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Karnik et al.

(54) **SYSTEM AND METHOD OF CONTINUOUS HEALTH MONITORING**

(71) Applicants: **Prasad Karnik**, Ladera Ranch, CA (US); **Sumukh Pathare**, Ladera Ranch, CA (US)

(72) Inventors: **Prasad Karnik**, Ladera Ranch, CA (US); **Sumukh Pathare**, Ladera Ranch, CA (US)

(21) Appl. No.: **16/133,309**

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A61B 5/00	(2006.01)
G16H 80/00	(2006.01)
G06F 3/0482	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 5/01*** (2013.01); ***A61B 5/0008*** (2013.01); ***G16H 80/00*** (2018.01); ***G06F 3/0482*** (2013.01); *A61B 2562/166* (2013.01); ***A61B 5/6831*** (2013.01); ***A61B 5/6833*** (2013.01); ***A61B 5/6804*** (2013.01); *A61B 2562/0271* (2013.01); ***A61B 5/4306*** (2013.01)

(57) **ABSTRACT**

The invention involves a system and method implementing a wearable device that employs a flexible printed circuit board (PCB), which includes a temperature sensor. The PCB may be printed on a flexible substrate that may be folded to form multiple layers configured to house the sensor and an antenna. The sensor may be housed within said layers and situated at a terminal end of a pathway that may be printed on the PCB, wherein the pathway acts as a contact as well as a conduit of heat from the body of the user to the sensor. The antenna may be housed within the layers of the flexible PCB in a manner such that proper signal transmission is preserved and latency is minimized. Temperature readings may be wirelessly communicated to one or more client devices, which implement one or more algorithms suitable for generating insights regarding health aspects of the user.

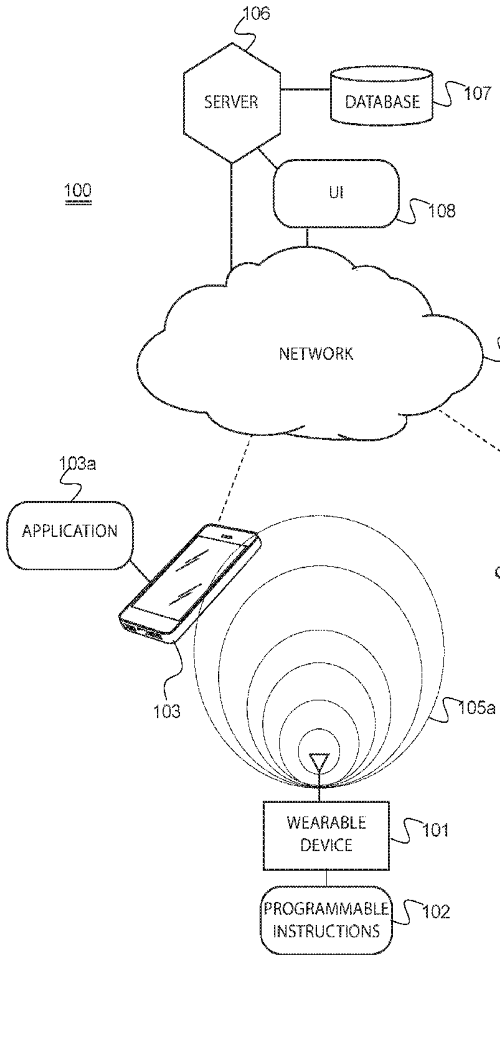


FIG. 1(a)

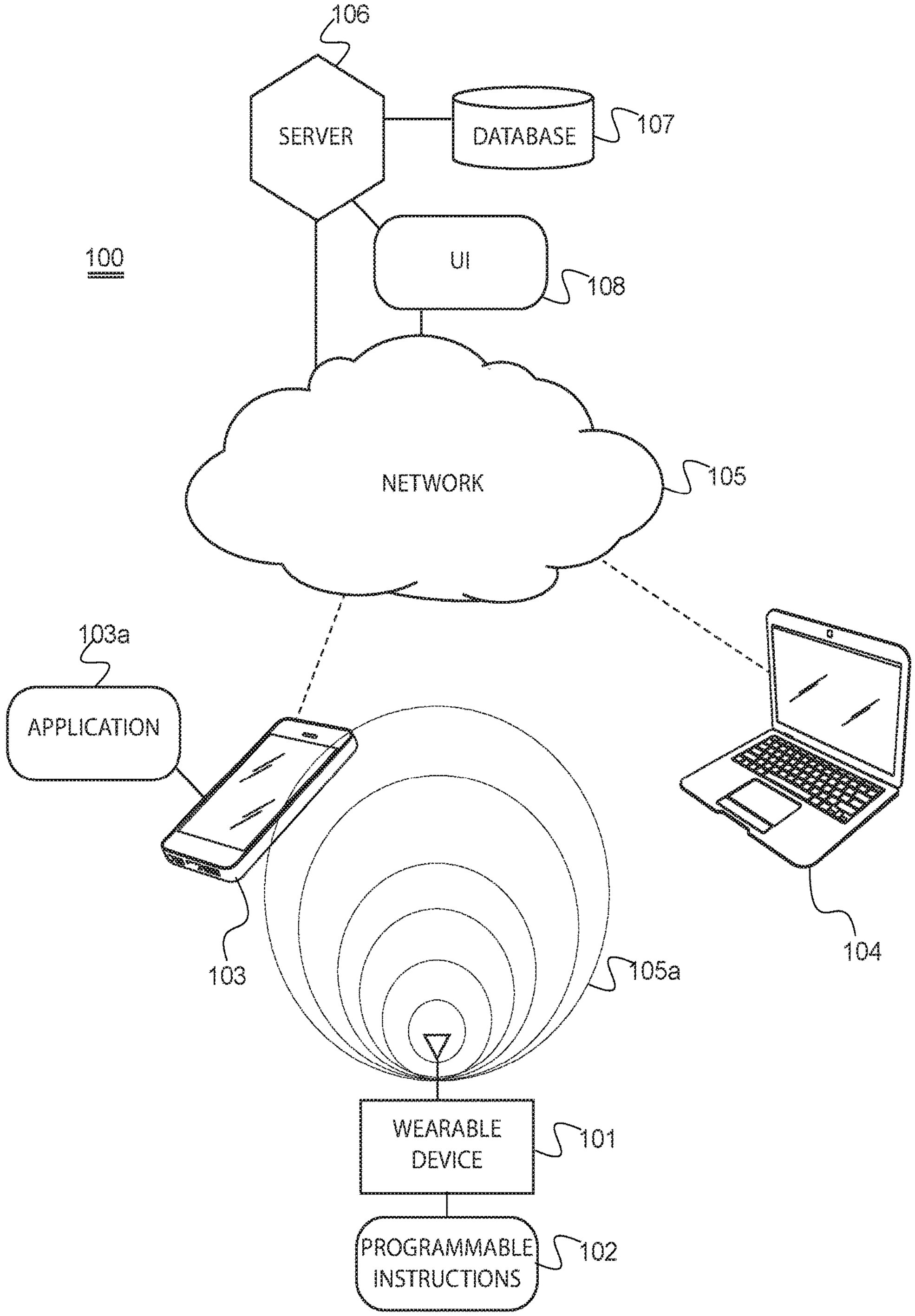

106
SERVER
DATABASE
107
100
UI
108
NETWORK
105
103a
APPLICATION
103
105a
104
WEARABLE DEVICE
101
PROGRAMMABLE INSTRUCTIONS
102

FIG. 1(b)

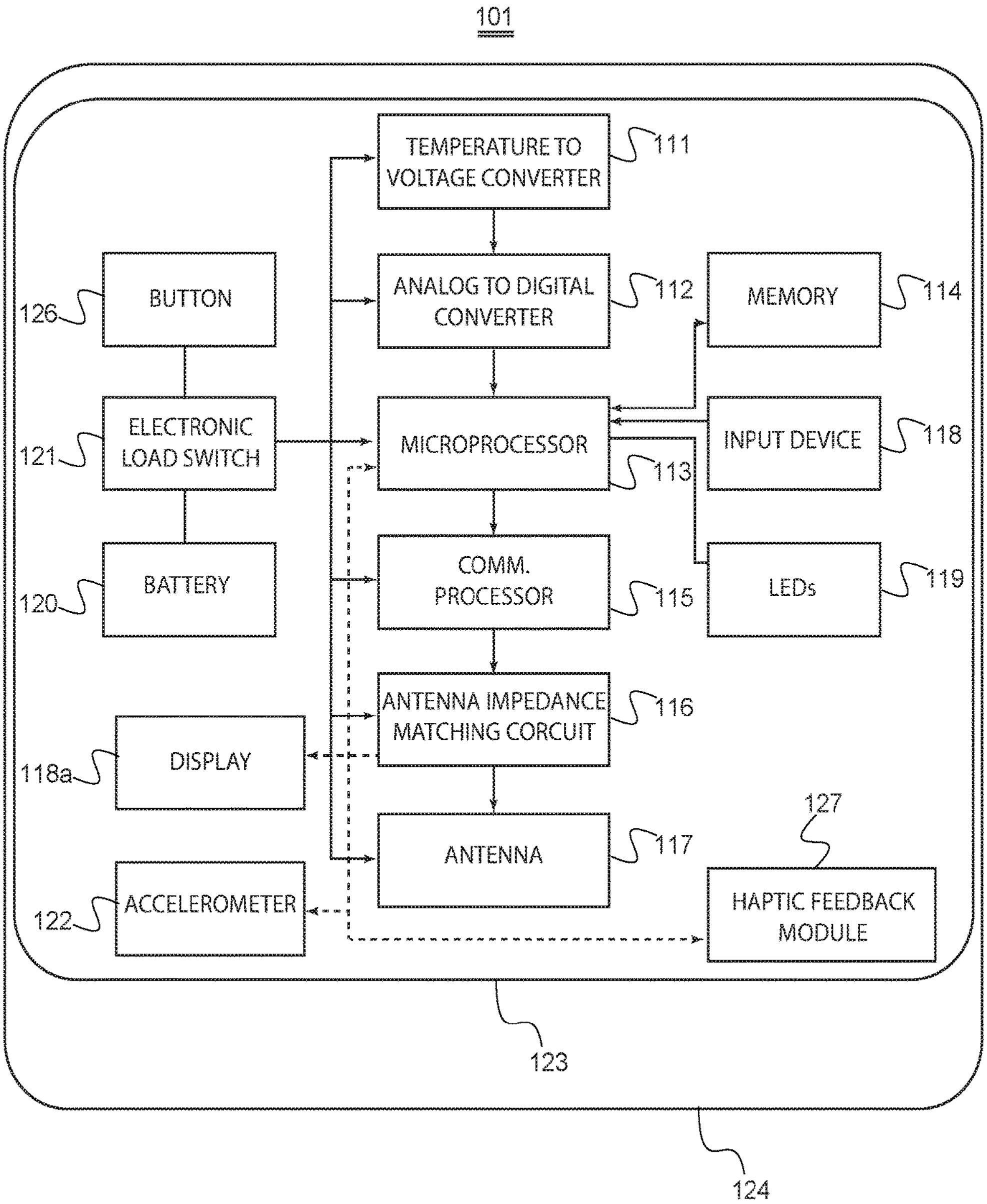

101
TEMPERATURE TO VOLTAGE CONVERTER
111
ANALOG TO DIGITAL CONVERTER
112
MEMORY
114
BUTTON
126
ELECTRONIC LOAD SWITCH
121
MICROPROCESSOR
113
INPUT DEVICE
118
BATTERY
120
COMM. PROCESSOR
115
LEDs
119
ANTENNA IMPEDANCE MATCHING CORCUIT
116
DISPLAY
118a
ANTENNA
117
127
HAPTIC FEEDBACK MODULE
ACCELEROMETER
122
123
124

FIG. 2(a)

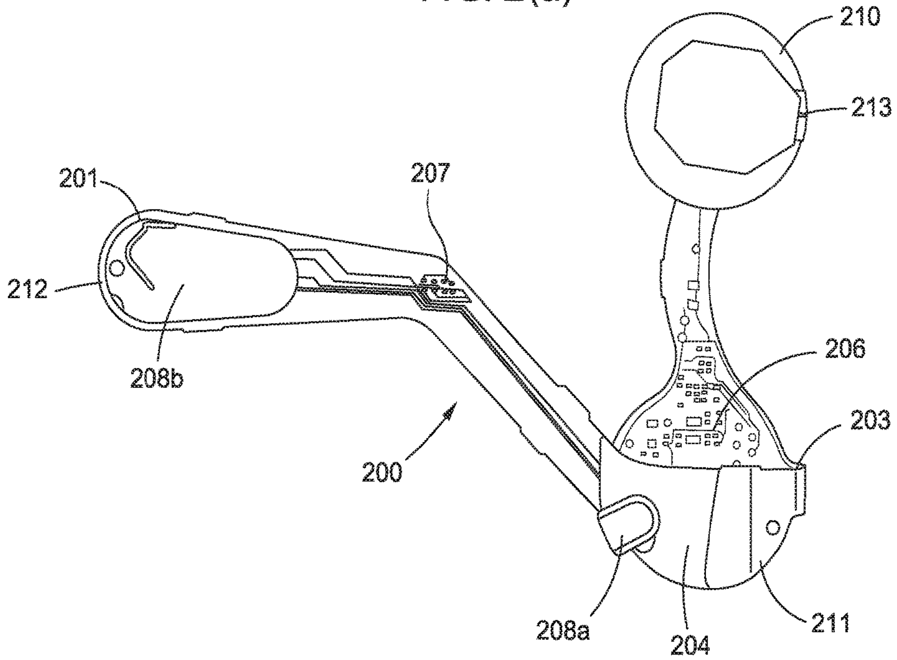

210
213
201
207
212
208b
206
203
200
208a
204
211

FIG. 2(b)

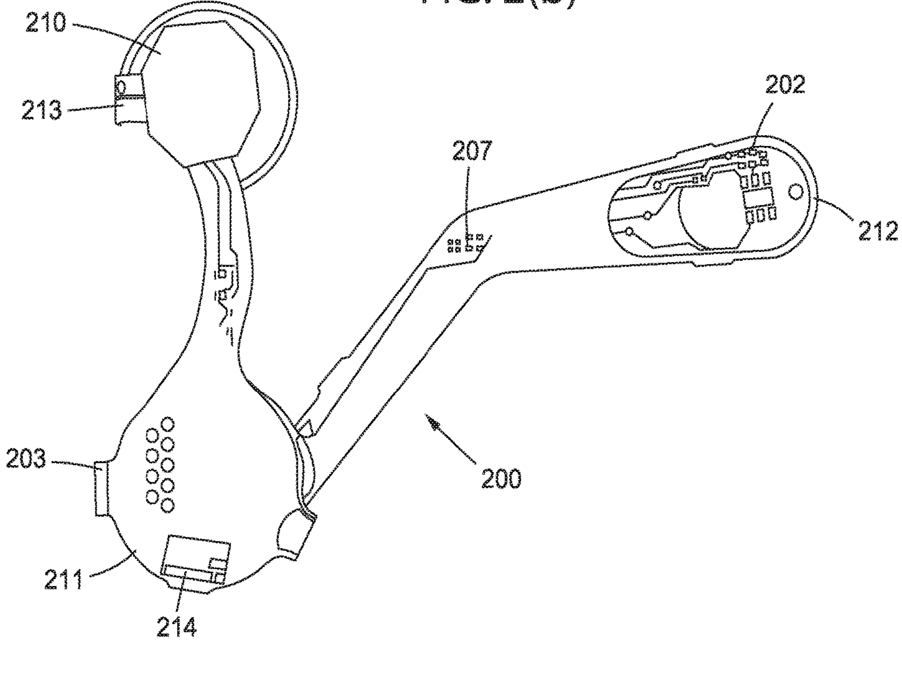

210
213
202
207
212
203
200
211
214

FIG. 2(c)

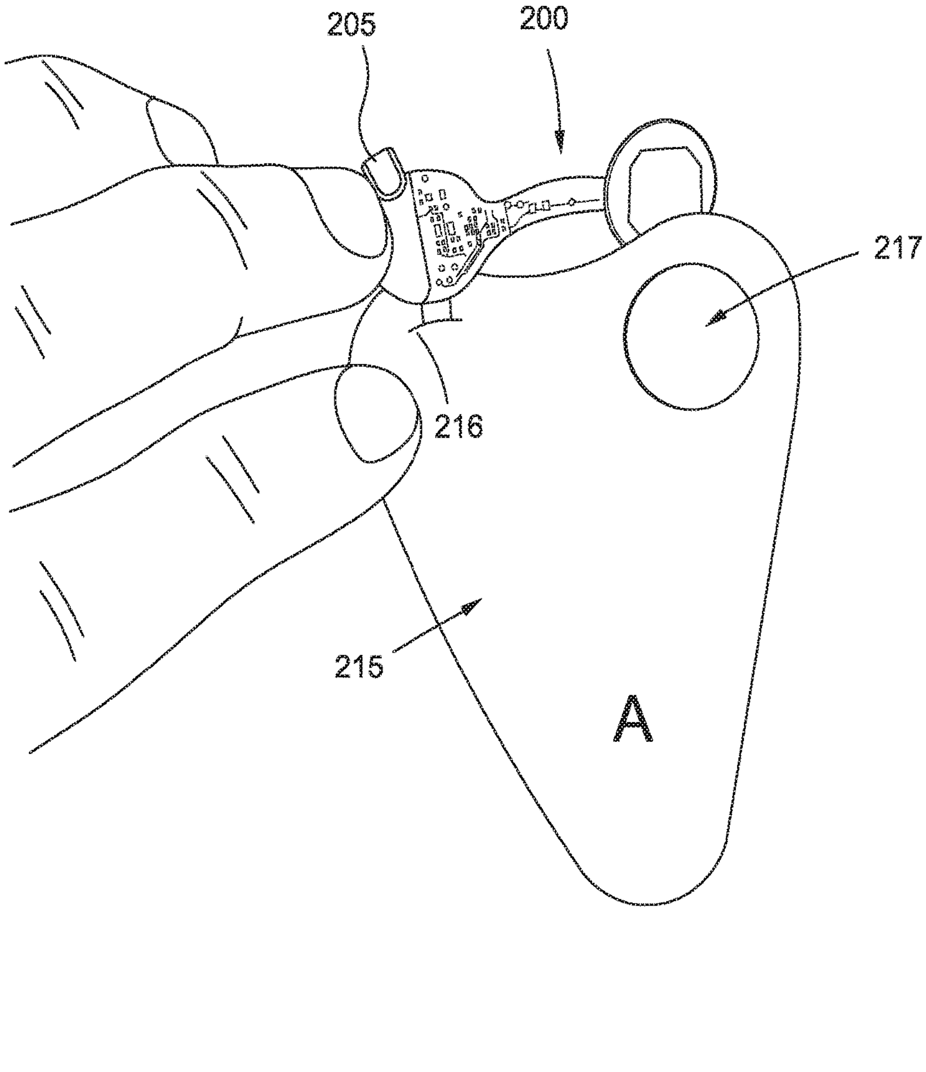


FIG. 2(d)

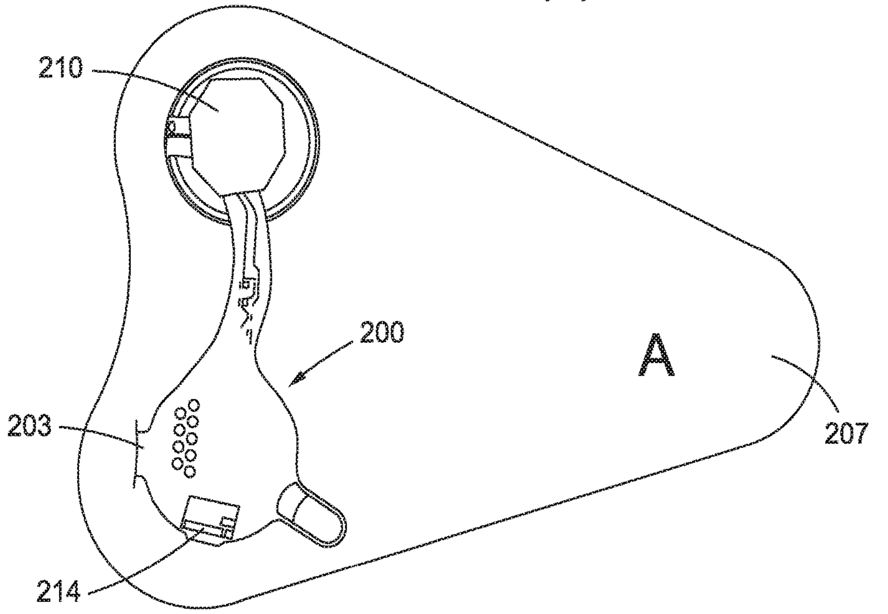


FIG. 2(e)

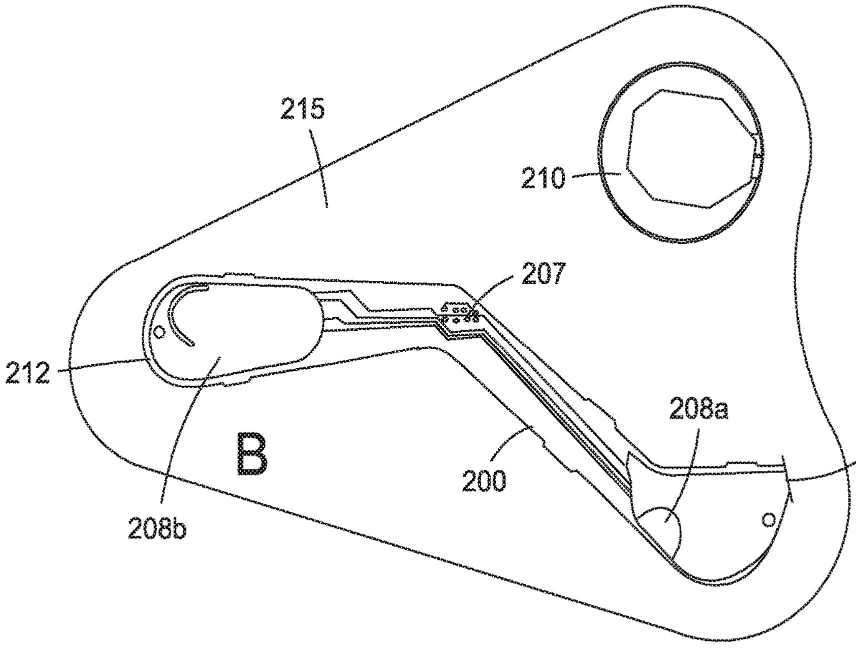


FIG. 3(a)

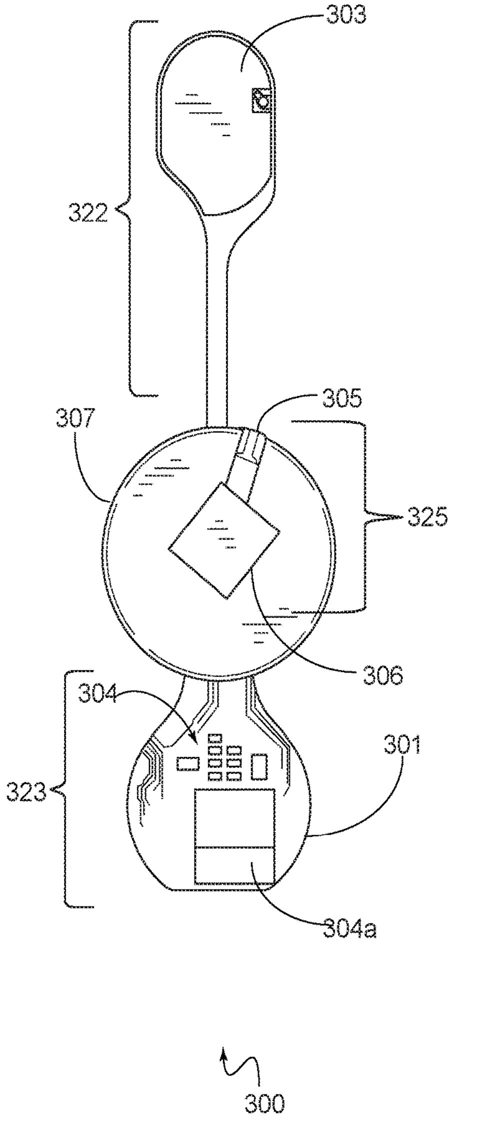

303
322
305
307
325
306
304
323
301
304a
300

FIG. 3(b)

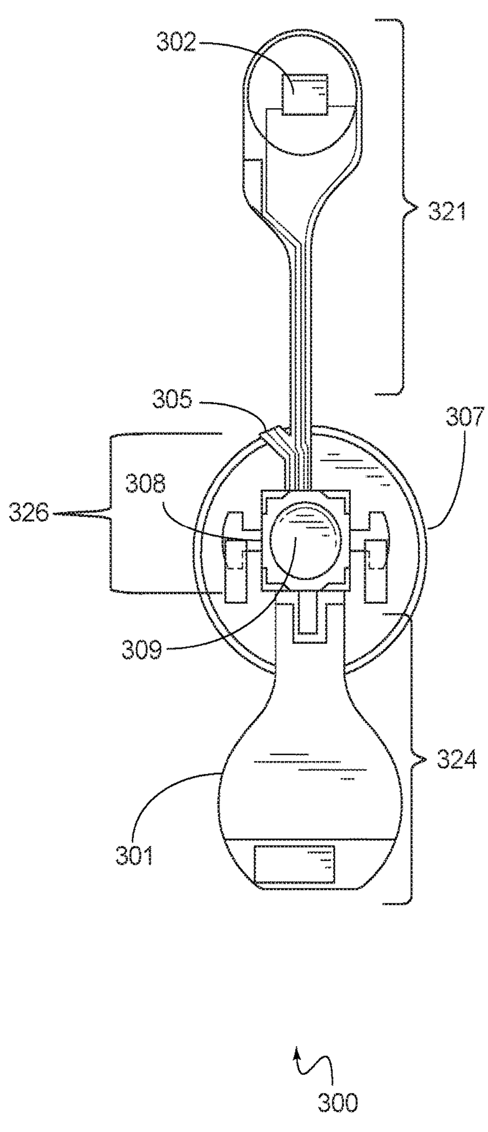

302
321
305
307
326
308
309
324
301
300

FIG. 3(c)

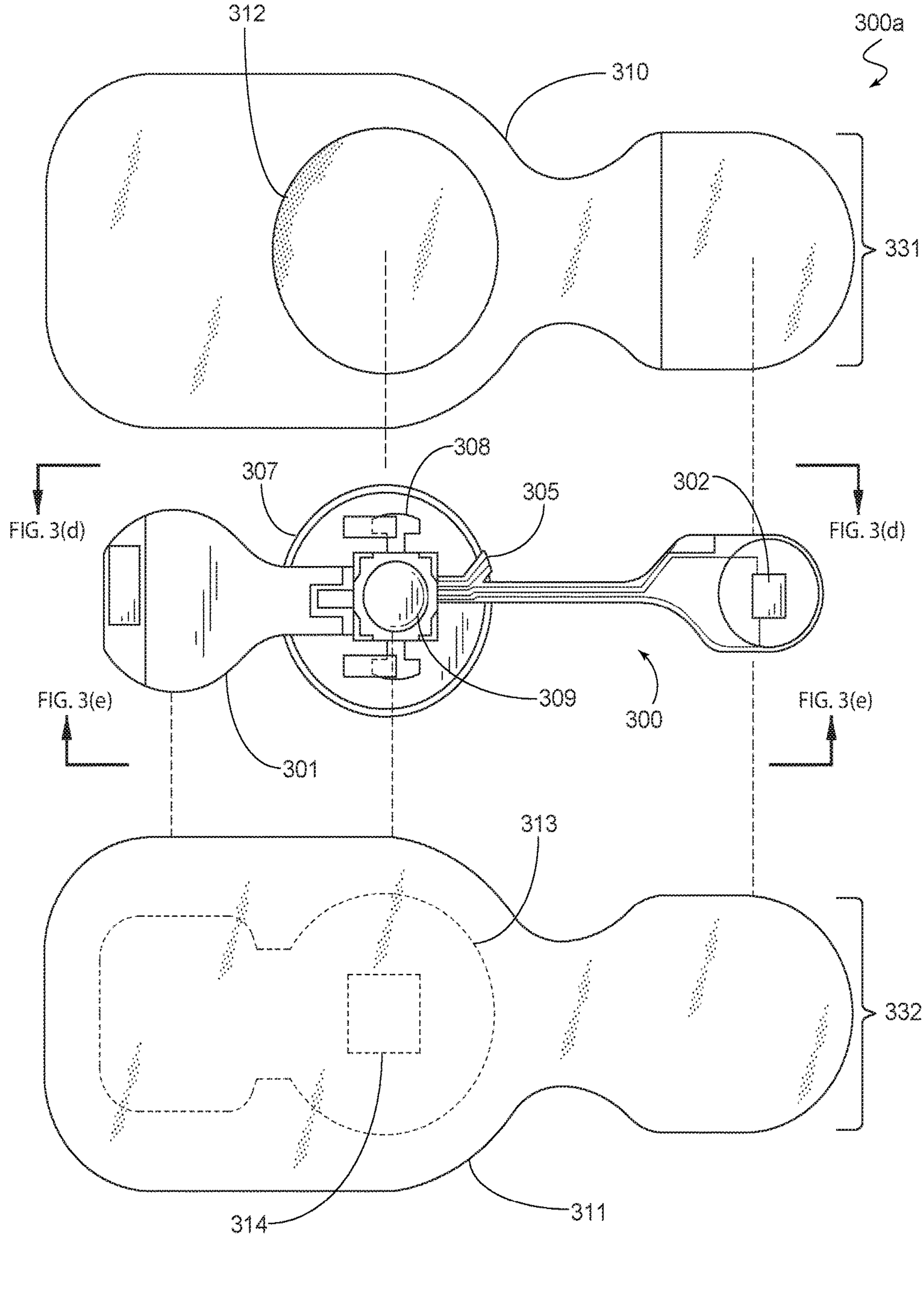

312
300a
310
331
308
307
305
302
FIG. 3(d)
FIG. 3(d)
309
FIG. 3(e)
FIG. 3(e)
300
301
313
332
311
314

FIG. 3(d)

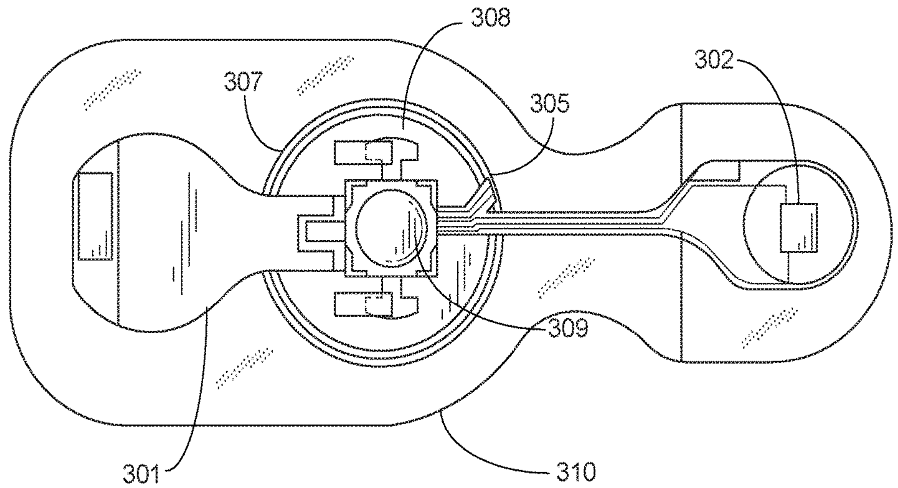


FIG. 3(e)

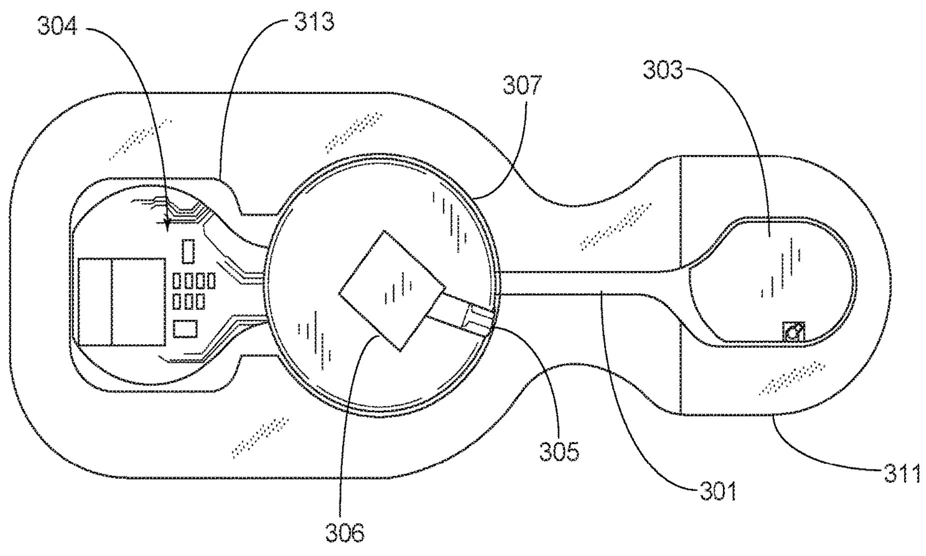


FIG. 3(f)

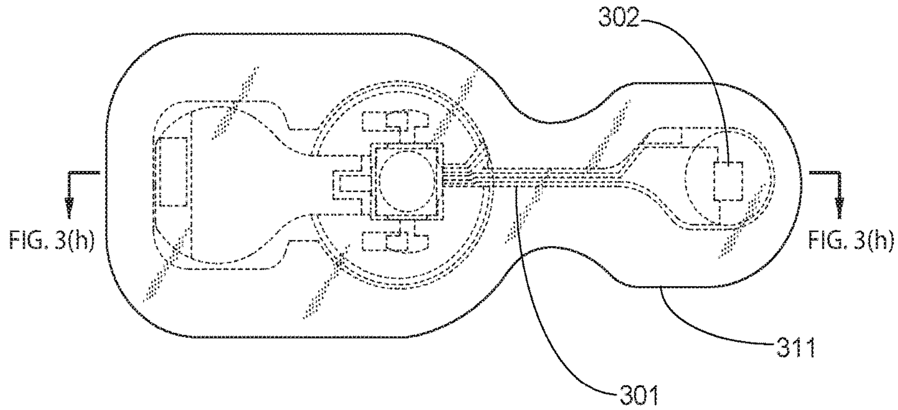


FIG. 3(g)

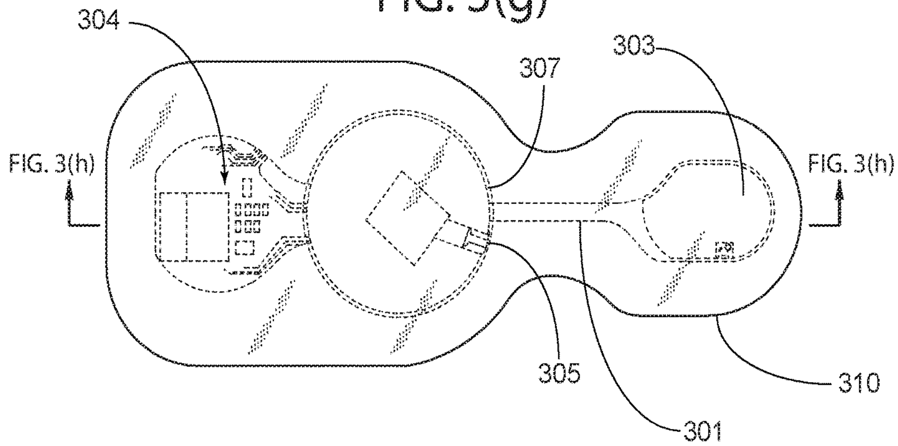


FIG. 3(h)

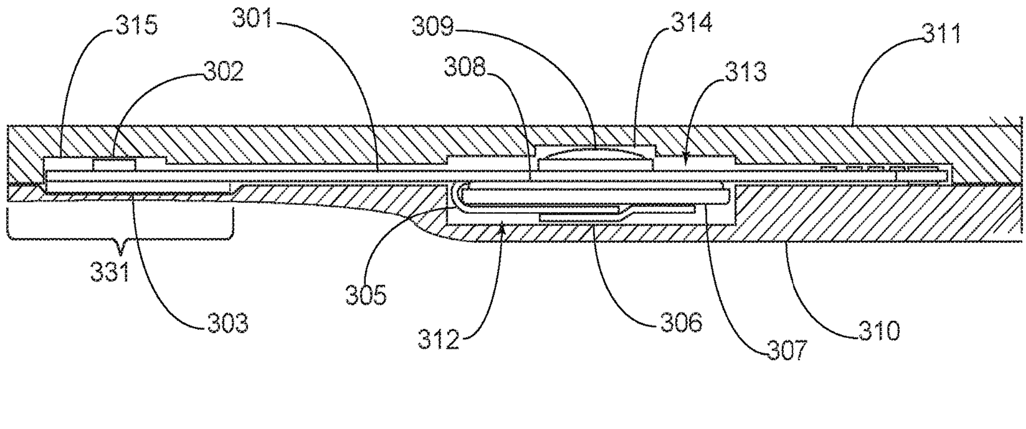


FIG. 3(i)

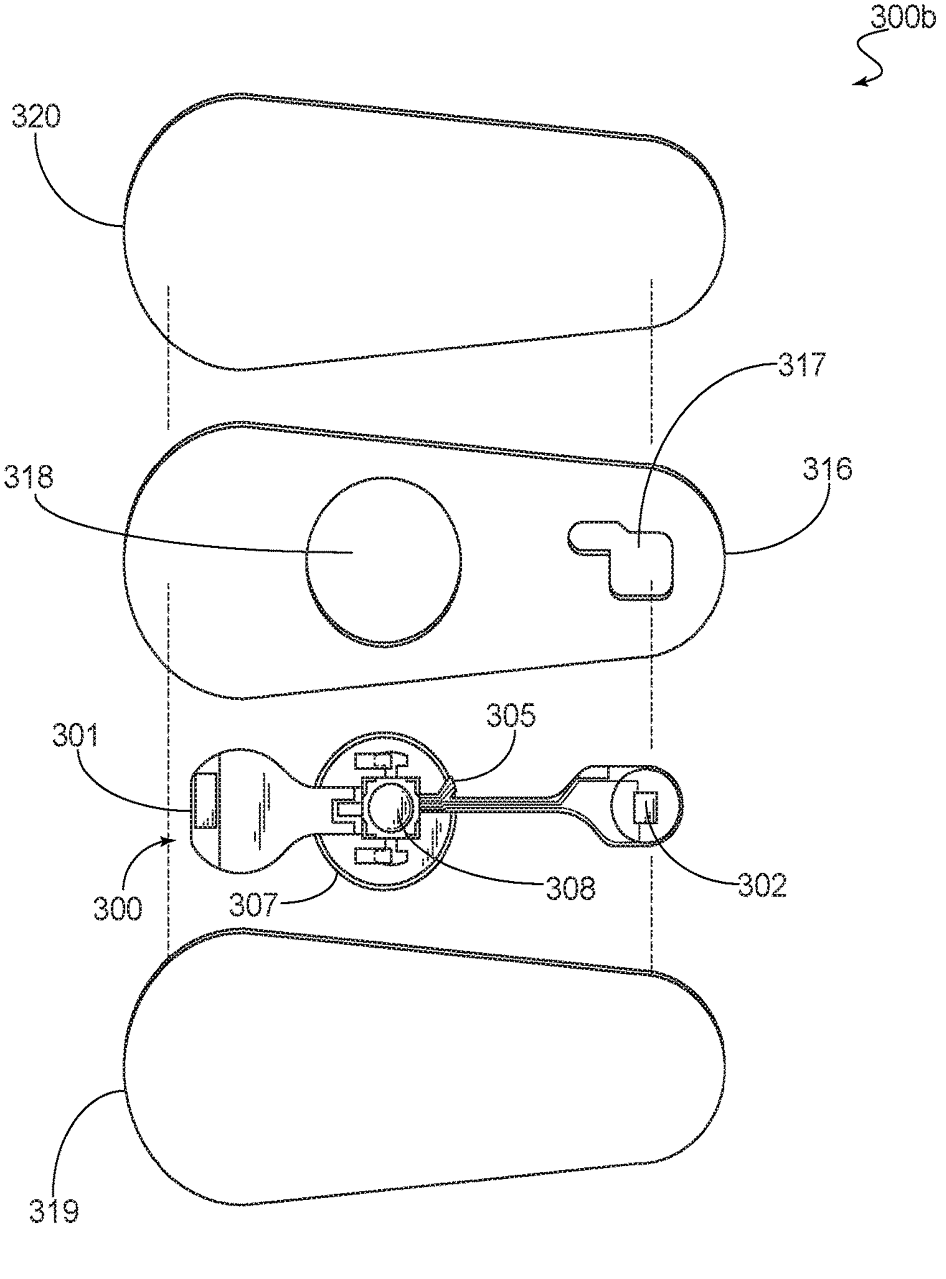


FIG. 3(j)

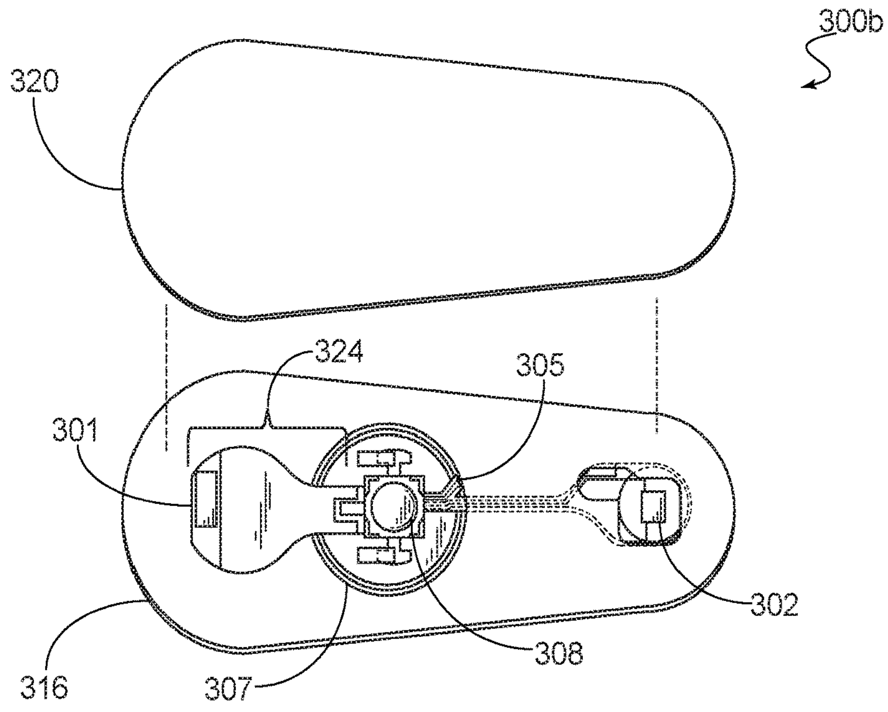


FIG. 3(k)

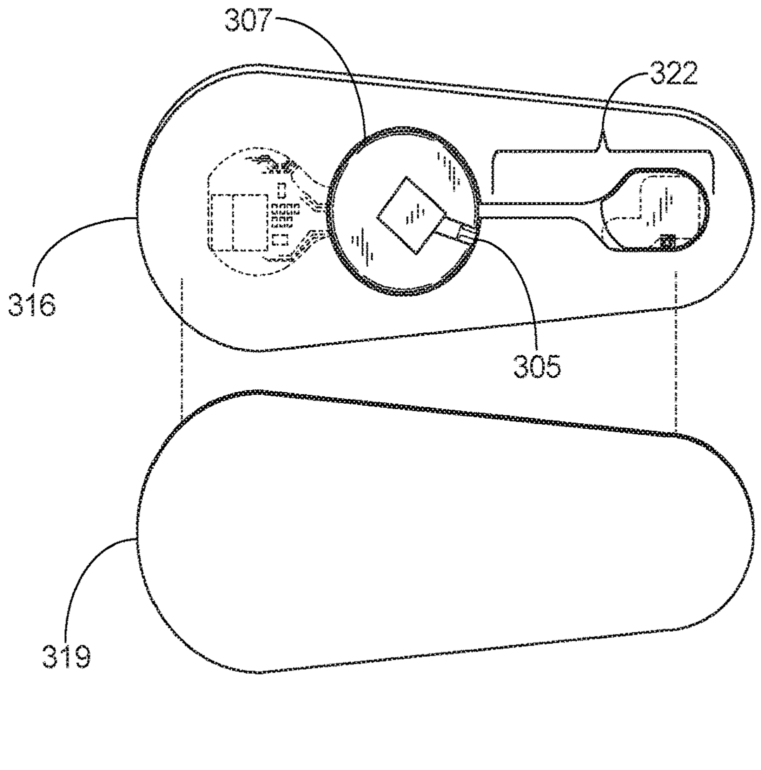
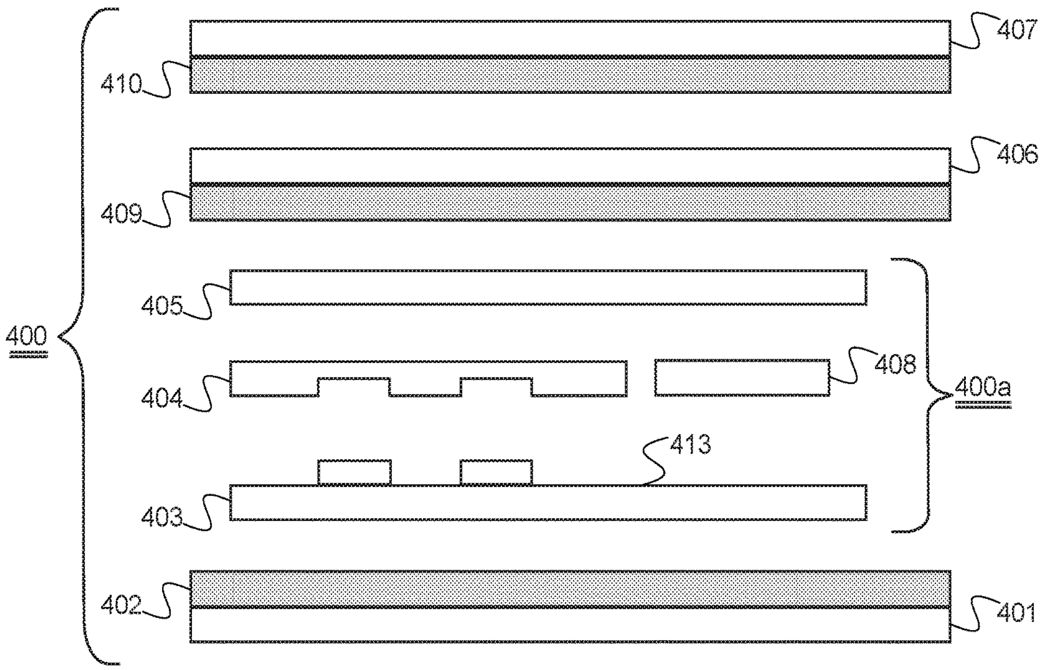
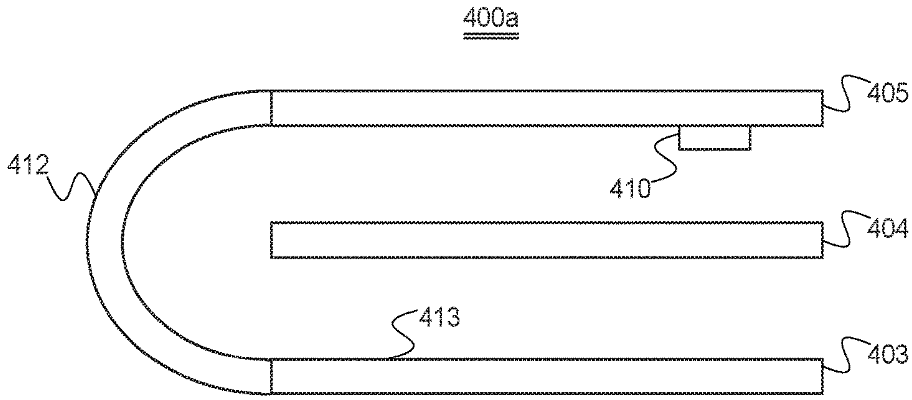


FIG. 4(a)



407
410
406
409
405
404
408
400a
400
413
403
402
401

FIG. 4(b)



400a
405
412
410
404
413
403

FIG. 4(c)

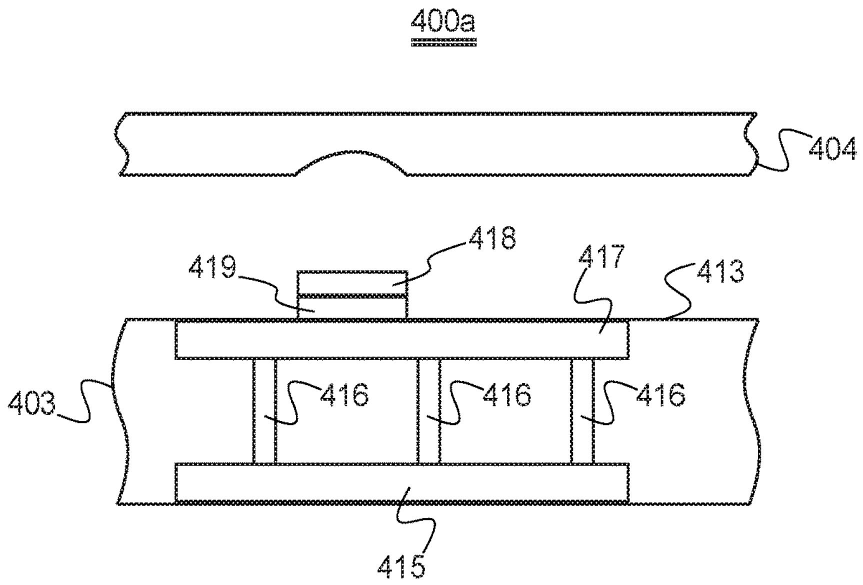


FIG. 4(d)

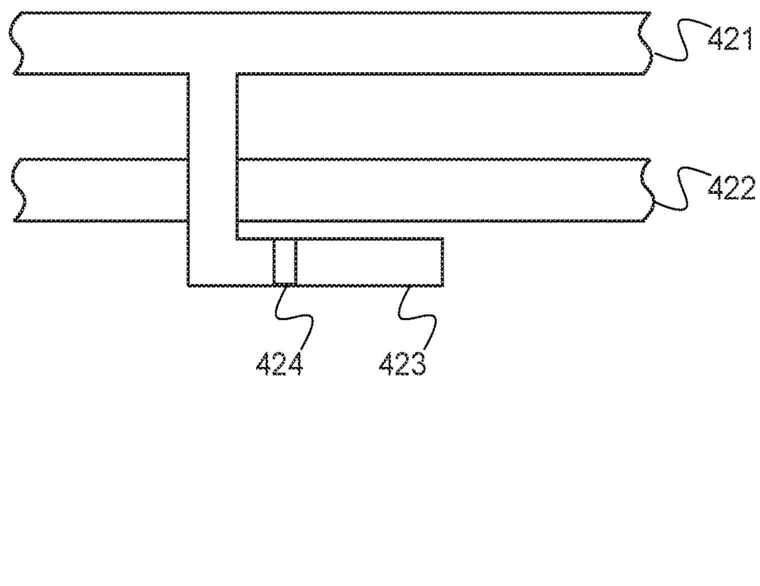


FIG. 5(a)

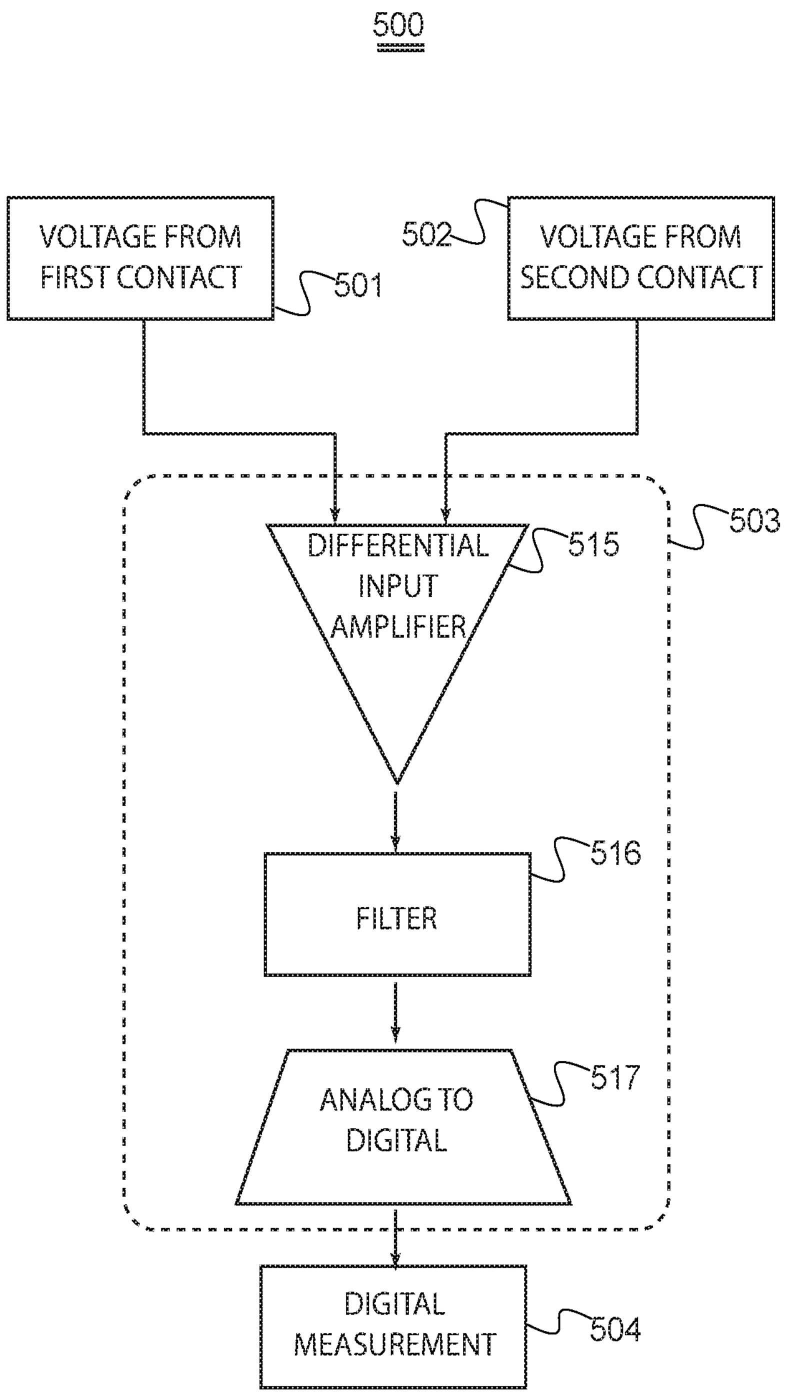

500
VOLTAGE FROM FIRST CONTACT
501
502
VOLTAGE FROM SECOND CONTACT
503
DIFFERENTIAL INPUT AMPLIFIER
515
FILTER
516
ANALOG TO DIGITAL
517
DIGITAL MEASUREMENT
504

FIG. 5(b)

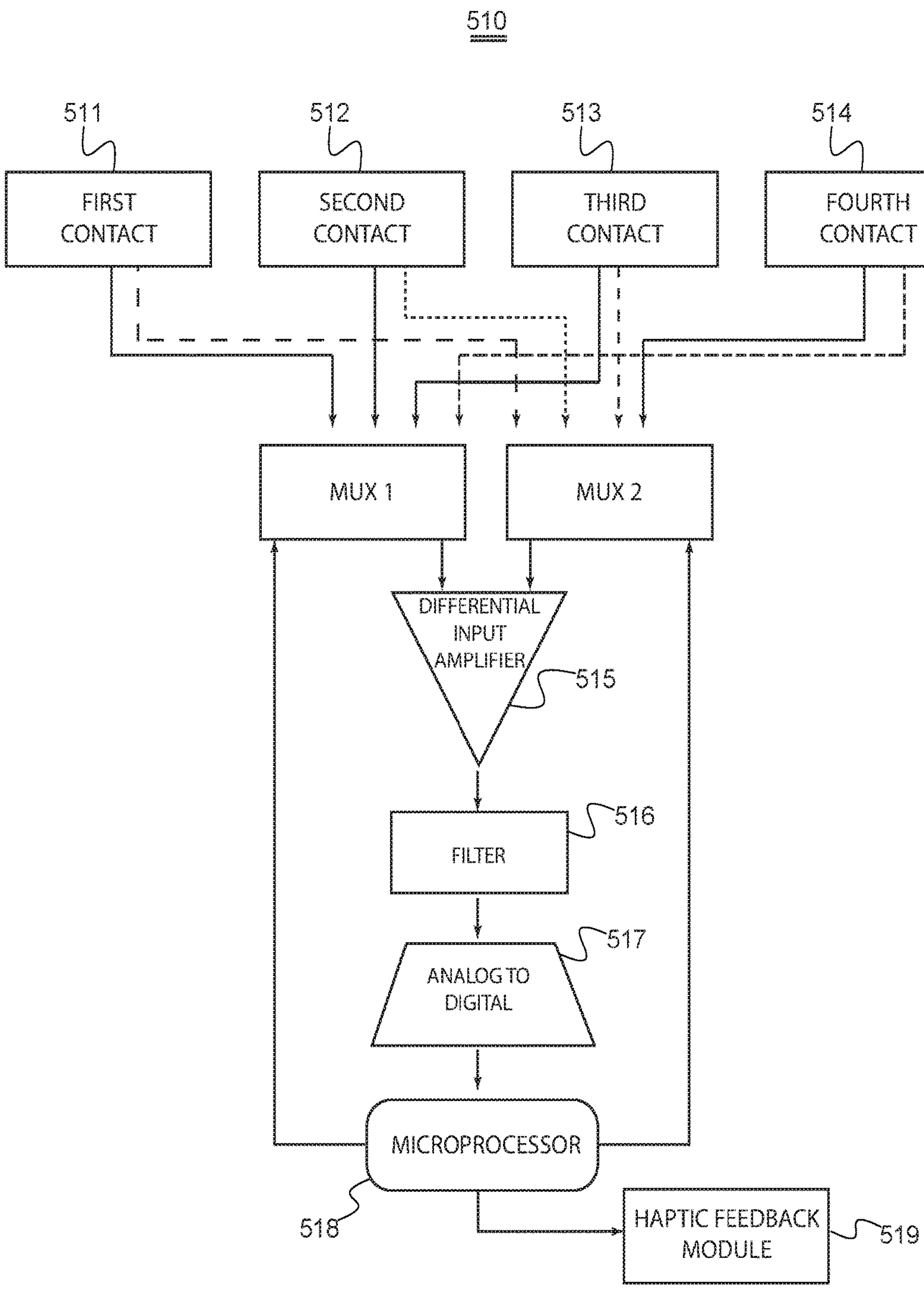

510
511
512
513
514
FIRST CONTACT
SECOND CONTACT
THIRD CONTACT
FOURTH CONTACT
MUX 1
MUX 2
DIFFERENTIAL INPUT AMPLIFIER
515
FILTER
516
ANALOG TO DIGITAL
517
MICROPROCESSOR
518
HAPTIC FEEDBACK MODULE
519

FIG. 5(c)

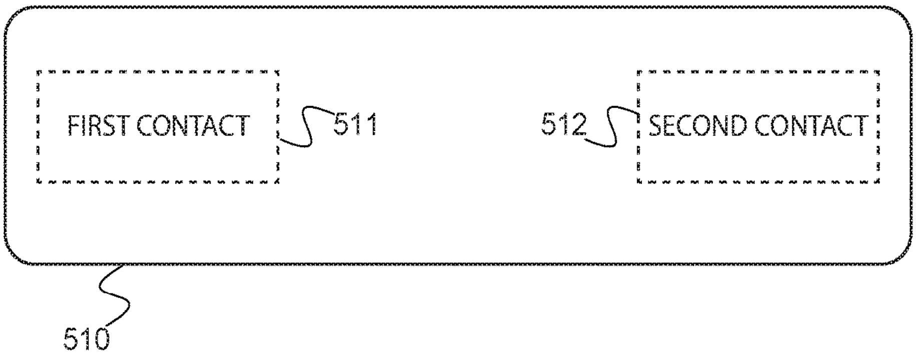

FIRST CONTACT
511
512
SECOND CONTACT
510

FIG. 5(d)

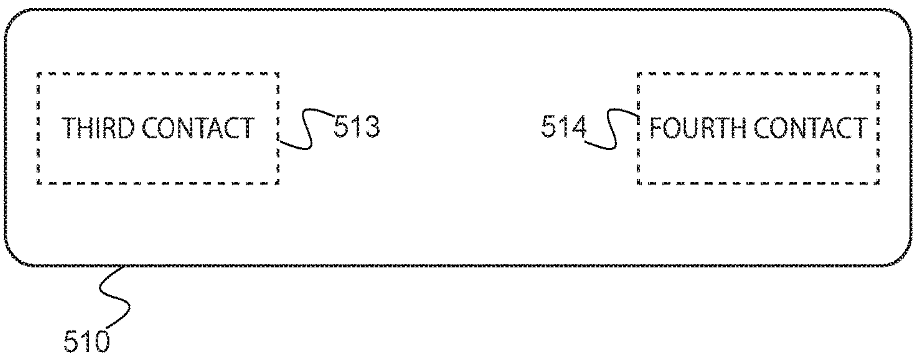

THIRD CONTACT
513
514
FOURTH CONTACT
510

FIG. 5(e)

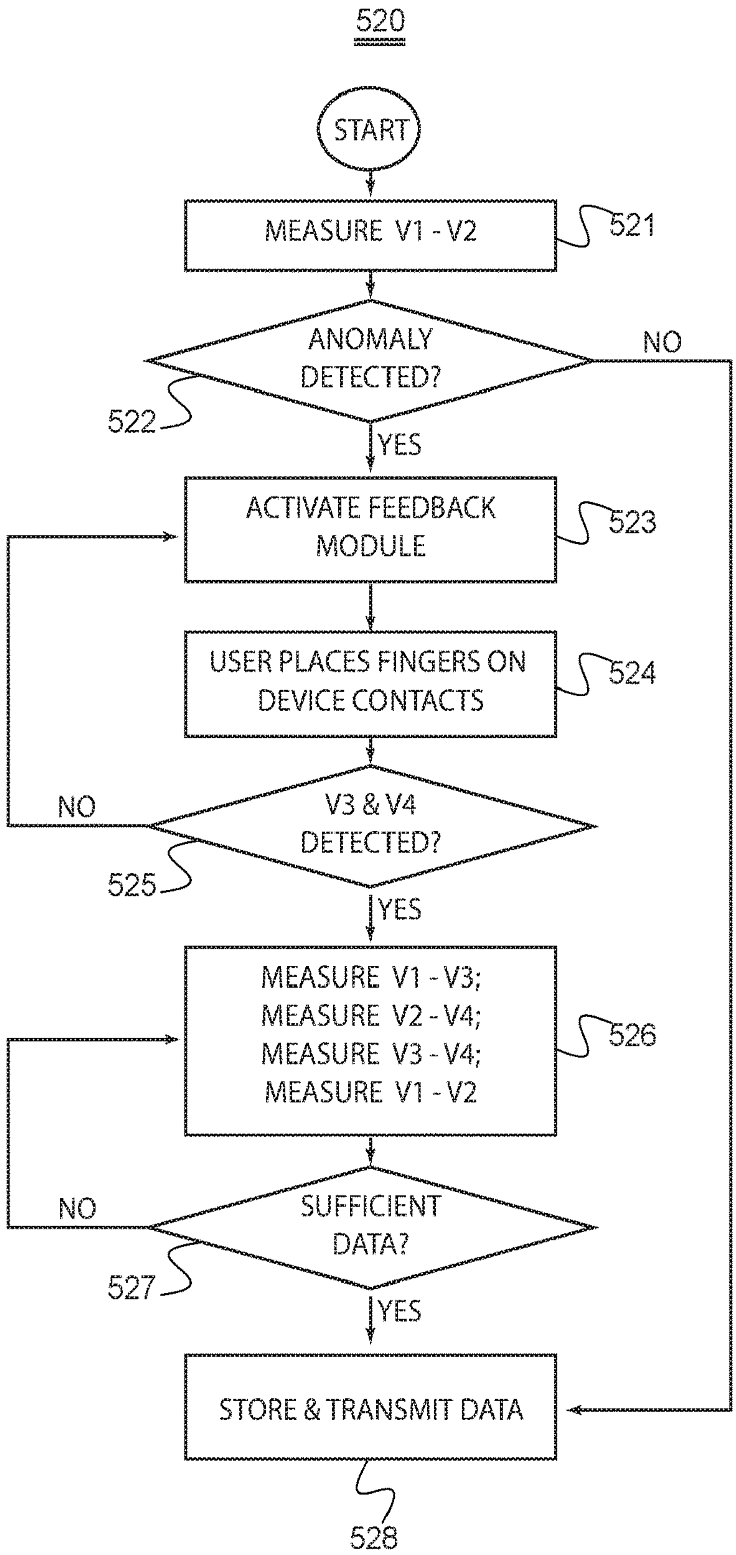

520
START
MEASURE V1 - V2
521
ANOMALY DETECTED?
NO
522
YES
ACTIVATE FEEDBACK MODULE
523
USER PLACES FINGERS ON DEVICE CONTACTS
524
NO
V3 & V4 DETECTED?
525
YES
MEASURE V1 - V3;
MEASURE V2 - V4;
MEASURE V3 - V4;
MEASURE V1 - V2
526
NO
SUFFICIENT DATA?
527
YES
STORE & TRANSMIT DATA
528

FIG. 6

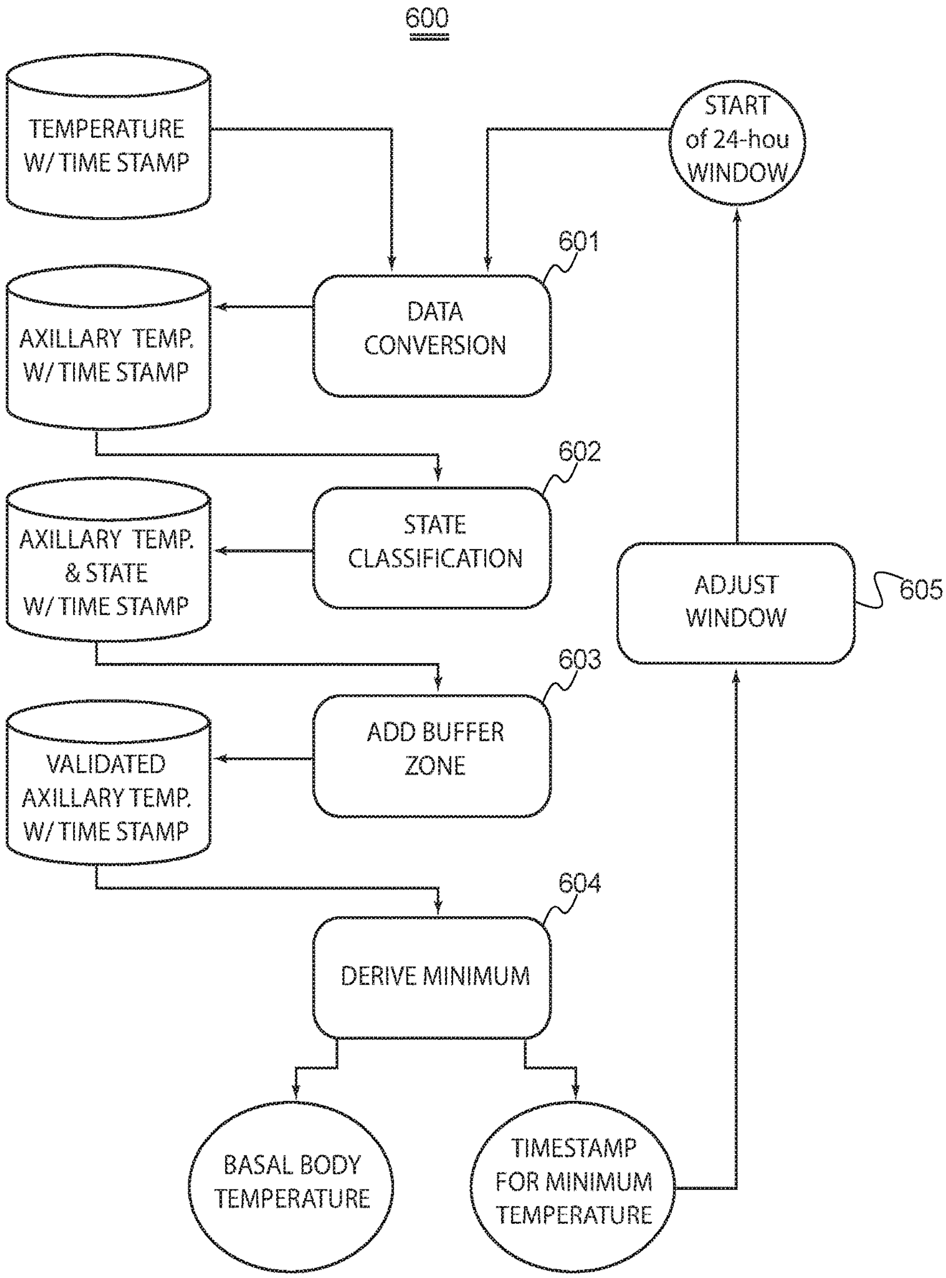

600
TEMPERATURE W/ TIME STAMP
START of 24-hou WINDOW
601
DATA CONVERSION
AXILLARY TEMP. W/ TIME STAMP
602
STATE CLASSIFICATION
AXILLARY TEMP. & STATE W/ TIME STAMP
ADJUST WINDOW
605
603
ADD BUFFER ZONE
VALIDATED AXILLARY TEMP. W/ TIME STAMP
604
DERIVE MINIMUM
BASAL BODY TEMPERATURE
TIMESTAMP FOR MINIMUM TEMPERATURE

FIG. 7(a)

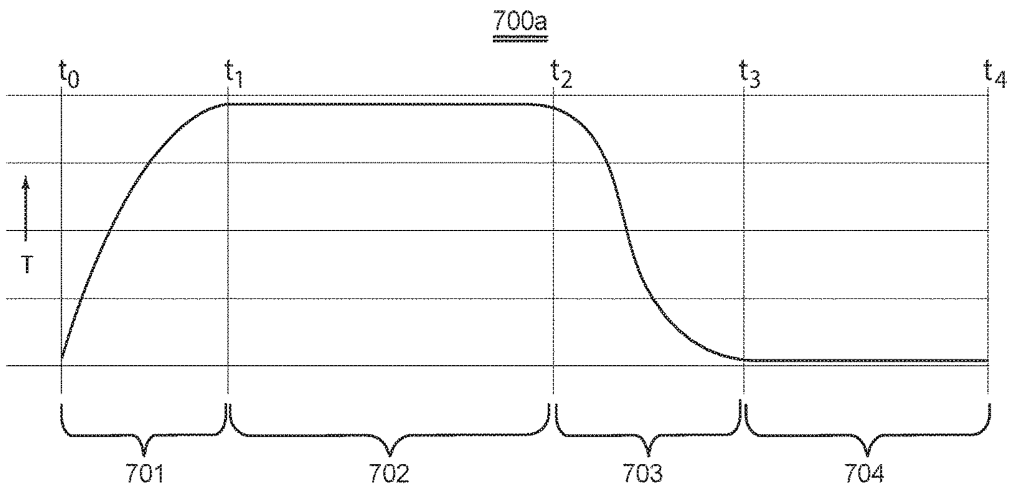

700a
t_0
t_1
t_2
t_3
t_4
T
701
702
703
704

FIG. 7(b)

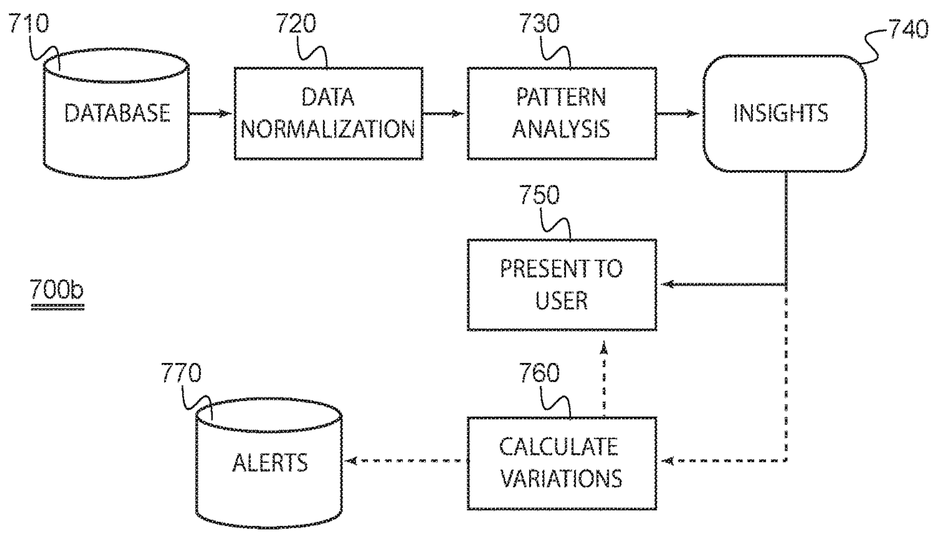

710
DATABASE
720
DATA NORMALIZATION
730
PATTERN ANALYSIS
740
INSIGHTS
750
PRESENT TO USER
700b
770
ALERTS
760
CALCULATE VARIATIONS

FIG. 7(c)

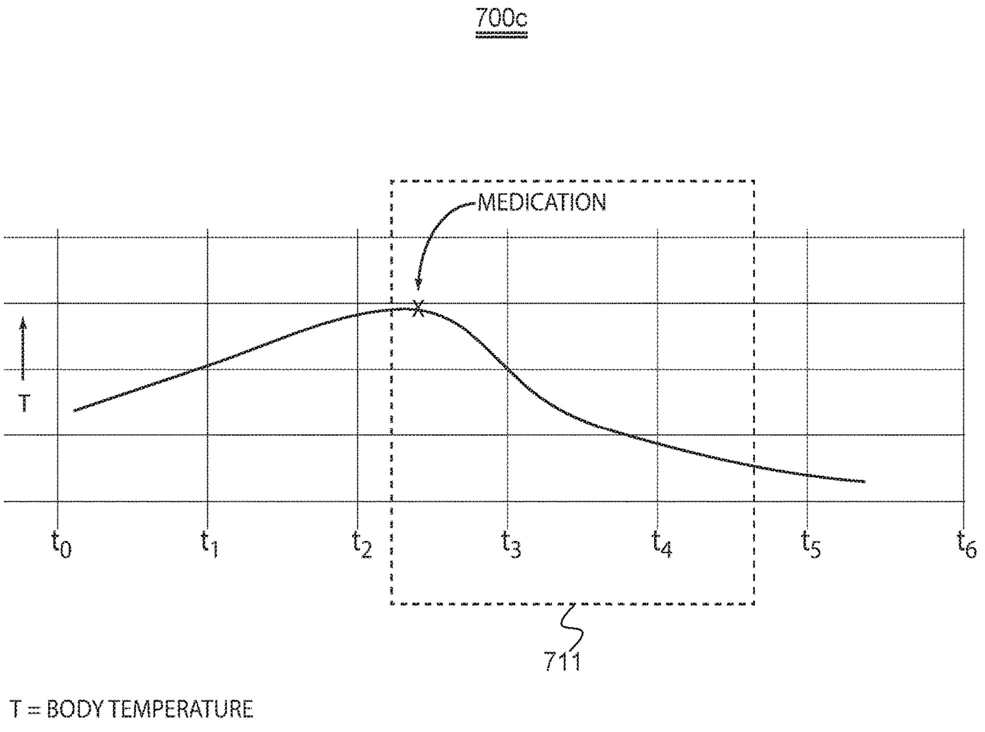
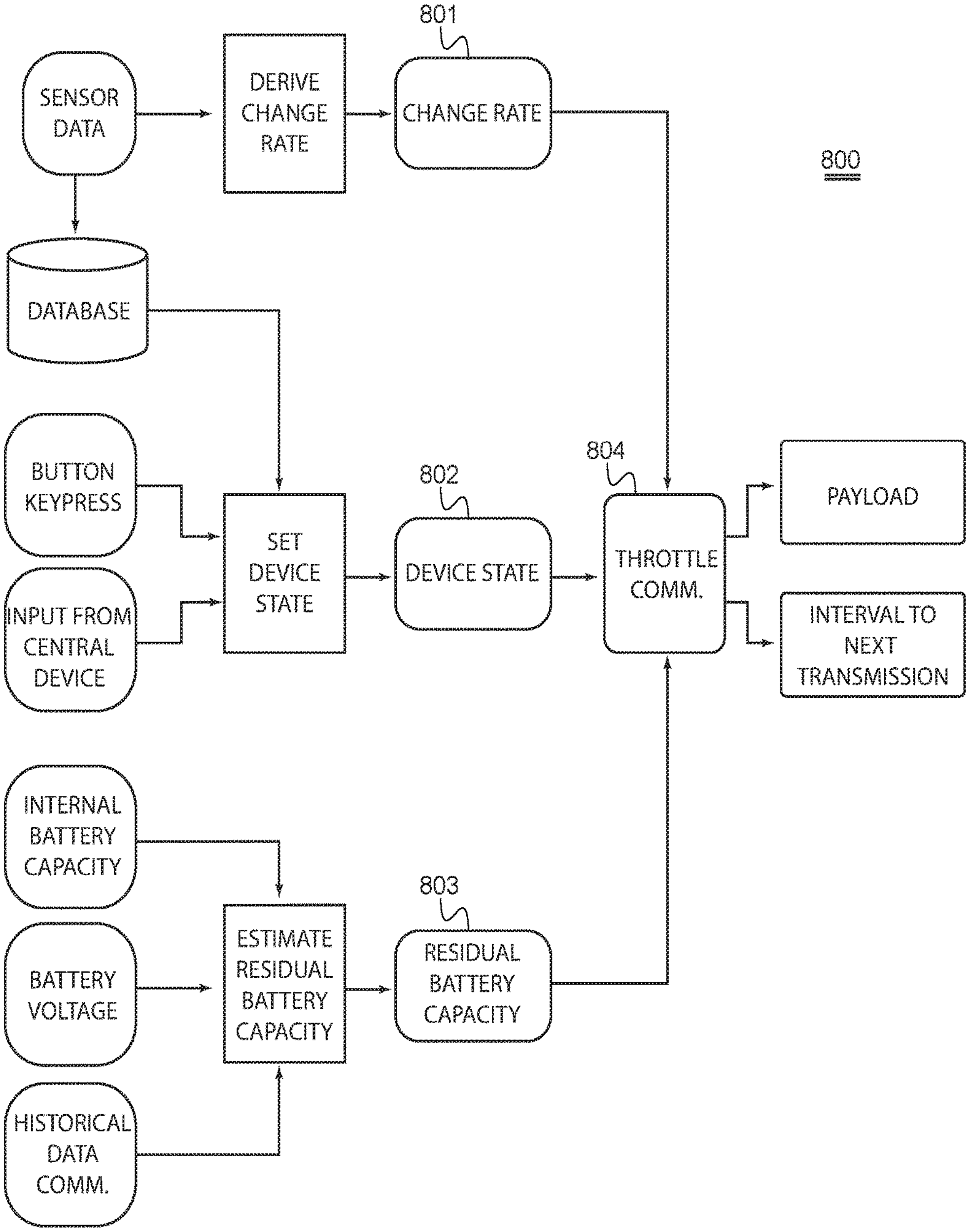
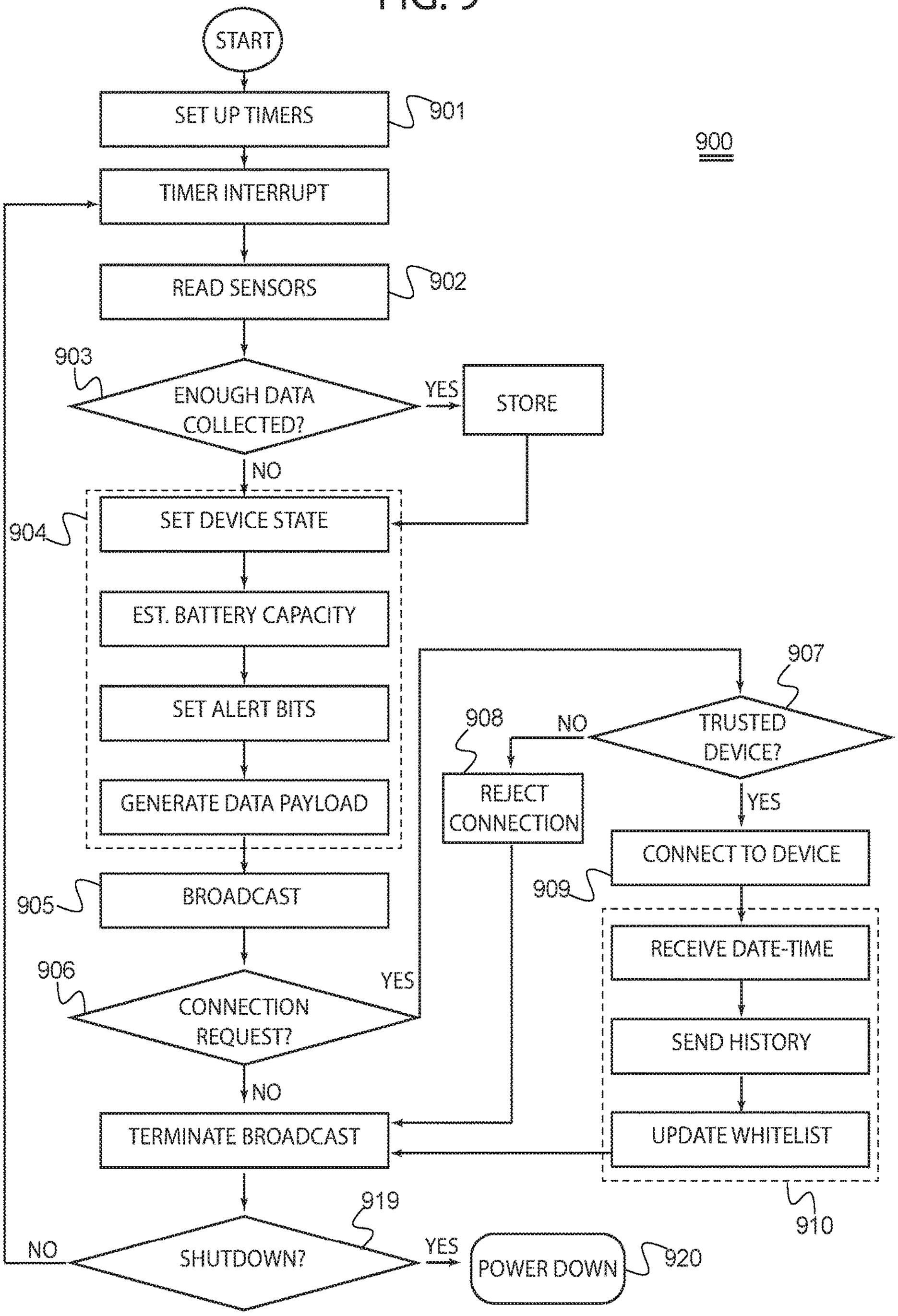


FIG. 8



801
SENSOR DATA
DERIVE CHANGE RATE
CHANGE RATE
800
DATABASE
BUTTON KEYPRESS
INPUT FROM CENTRAL DEVICE
SET DEVICE STATE
802
DEVICE STATE
804
THROTTLE COMM.
PAYLOAD
INTERVAL TO NEXT TRANSMISSION
INTERNAL BATTERY CAPACITY
BATTERY VOLTAGE
HISTORICAL DATA COMM.
ESTIMATE RESIDUAL BATTERY CAPACITY
803
RESIDUAL BATTERY CAPACITY

FIG. 9



START
SET UP TIMERS
901
900
TIMER INTERRUPT
READ SENSORS
902
903
ENOUGH DATA COLLECTED?
YES
STORE
NO
904
SET DEVICE STATE
EST. BATTERY CAPACITY
SET ALERT BITS
GENERATE DATA PAYLOAD
907
TRUSTED DEVICE?
908
NO
REJECT CONNECTION
YES
CONNECT TO DEVICE
909
905
BROADCAST
RECEIVE DATE-TIME
906
YES
CONNECTION REQUEST?
SEND HISTORY
NO
TERMINATE BROADCAST
UPDATE WHITELIST
910
919
NO
SHUTDOWN?
YES
POWER DOWN
920

FIG. 10

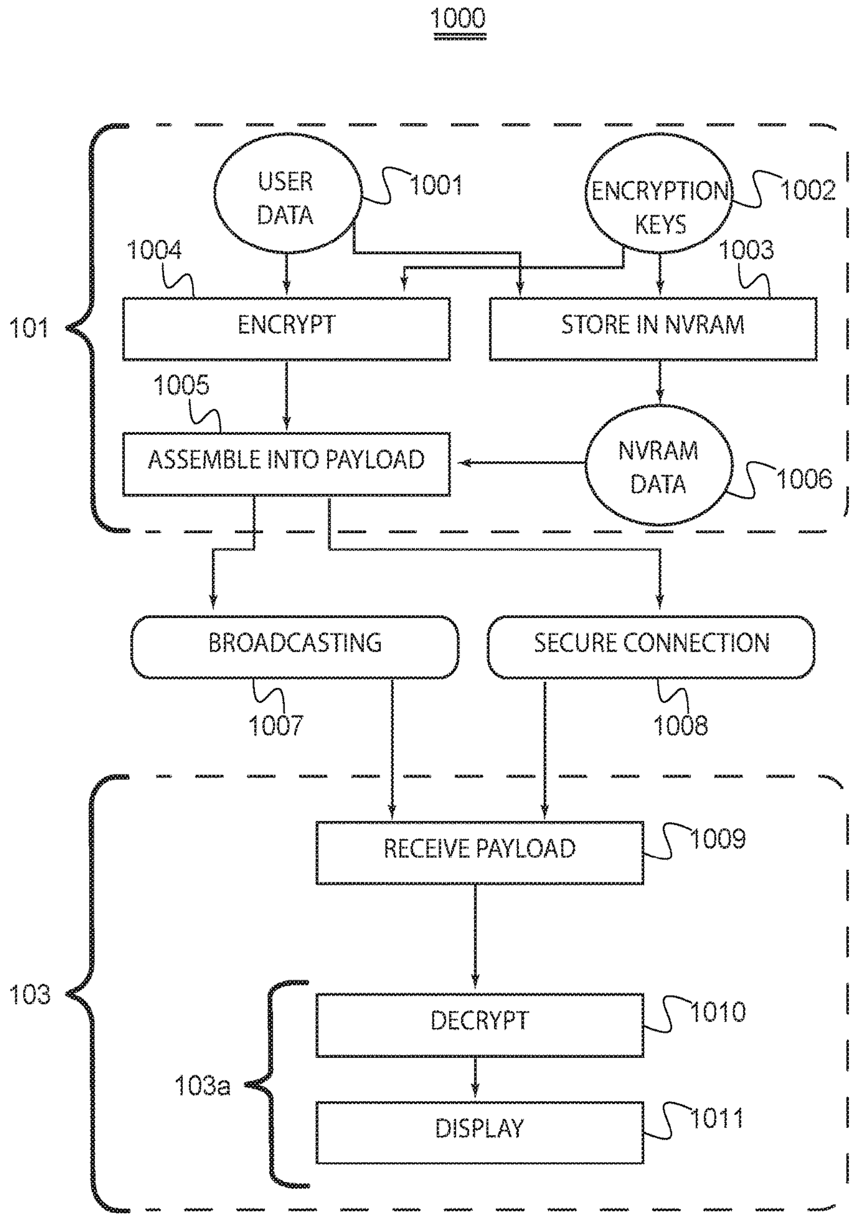

1000
USER DATA
1001
ENCRYPTION KEYS
1002
1004
1003
101
ENCRYPT
STORE IN NVRAM
1005
ASSEMBLE INTO PAYLOAD
NVRAM DATA
1006
BROADCASTING
SECURE CONNECTION
1007
1008
RECEIVE PAYLOAD
1009
103
DECRYPT
1010
103a
DISPLAY
1011

FIG. 11

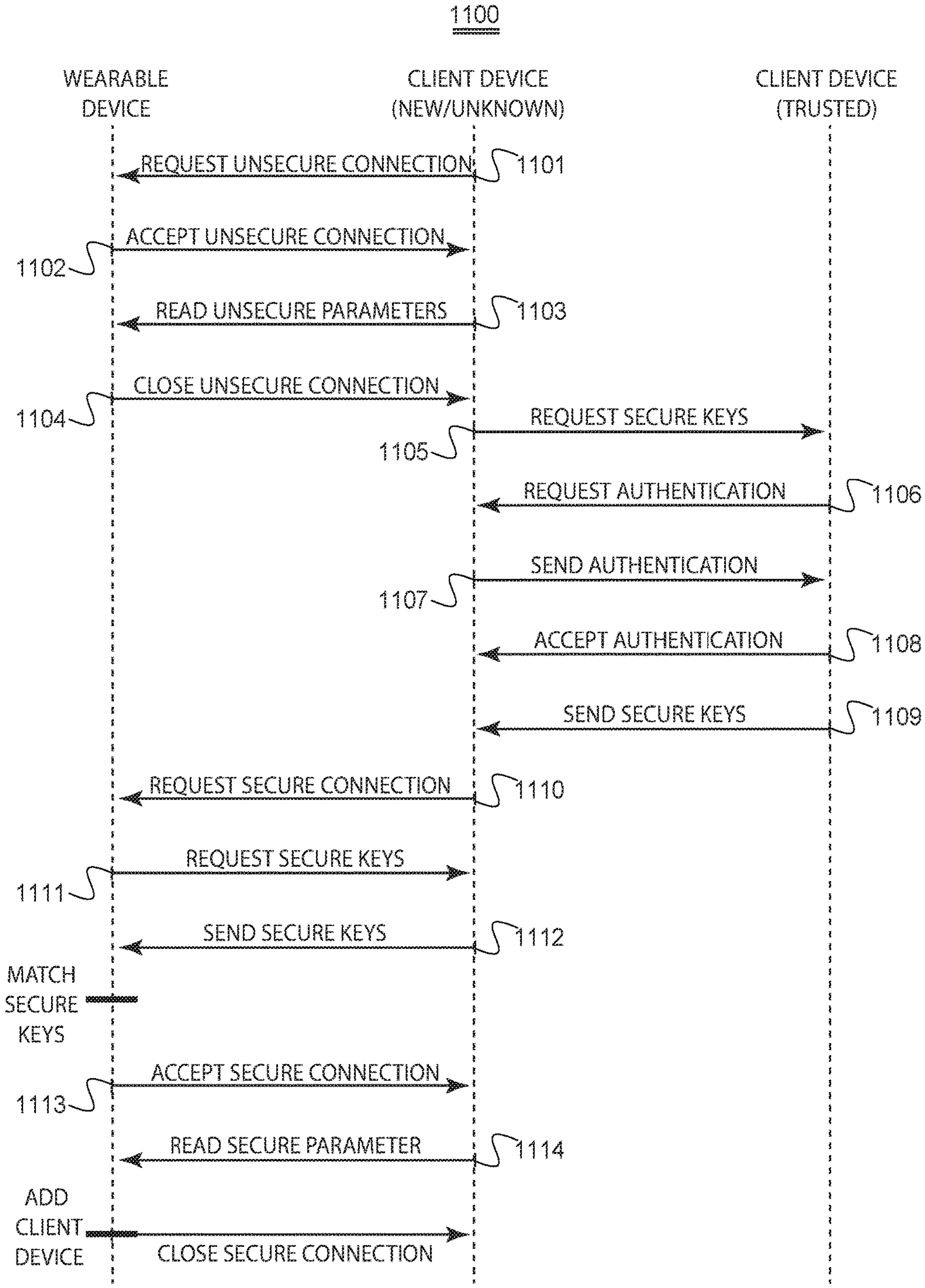

1100
WEARABLE DEVICE
CLIENT DEVICE (NEW/UNKNOWN)
CLIENT DEVICE (TRUSTED)
REQUEST UNSECURE CONNECTION
1101
ACCEPT UNSECURE CONNECTION
1102
READ UNSECURE PARAMETERS
1103
CLOSE UNSECURE CONNECTION
1104
REQUEST SECURE KEYS
1105
REQUEST AUTHENTICATION
1106
SEND AUTHENTICATION
1107
ACCEPT AUTHENTICATION
1108
SEND SECURE KEYS
1109
REQUEST SECURE CONNECTION
1110
REQUEST SECURE KEYS
1111
SEND SECURE KEYS
1112
MATCH SECURE KEYS
ACCEPT SECURE CONNECTION
1113
READ SECURE PARAMETER
1114
ADD CLIENT DEVICE
CLOSE SECURE CONNECTION

FIG. 12

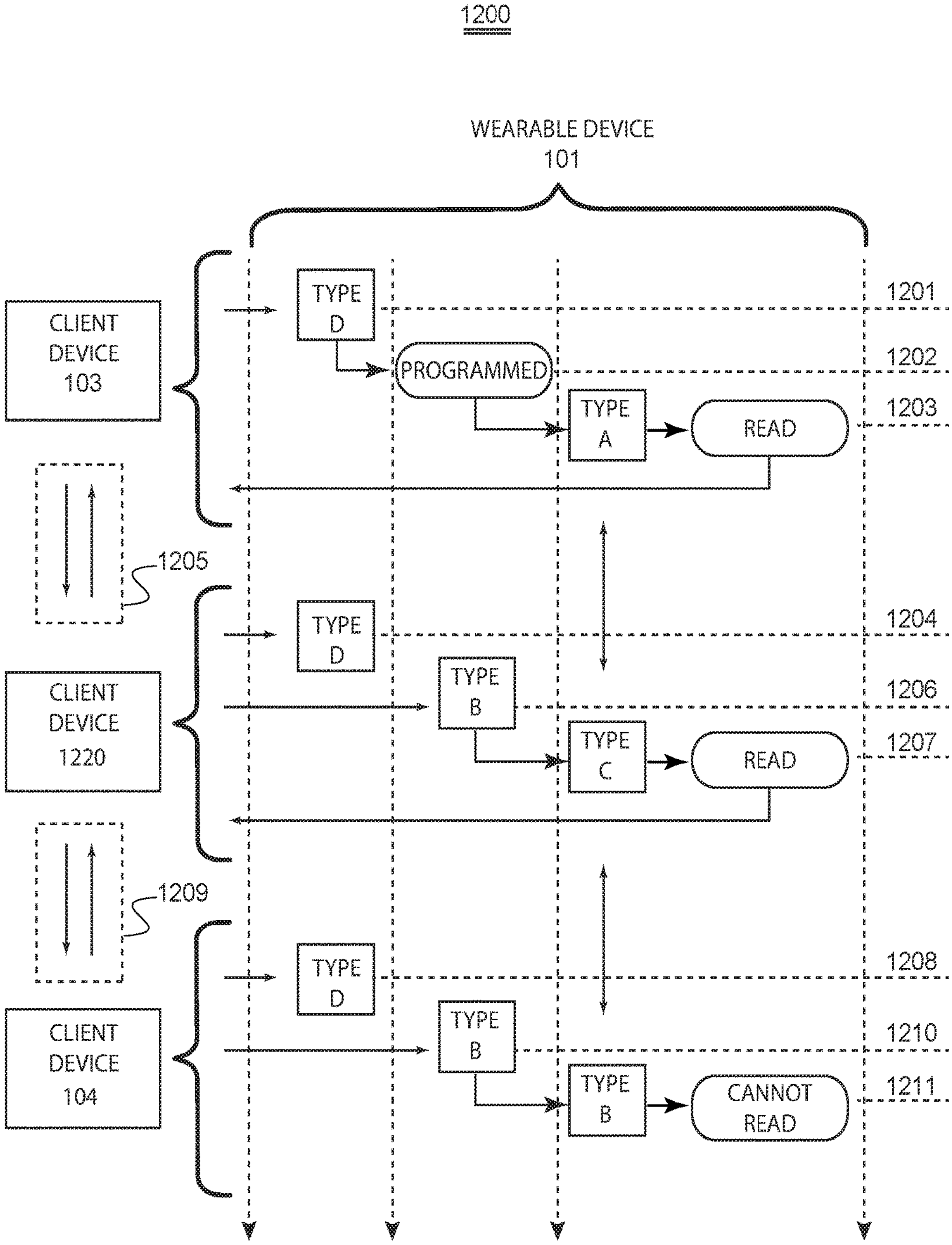

1200
WEARABLE DEVICE
101
CLIENT
DEVICE
103
TYPE
D
1201
PROGRAMMED
1202
TYPE
A
READ
1203
1205
CLIENT
DEVICE
1220
TYPE
D
1204
TYPE
B
1206
TYPE
C
READ
1207
1209
CLIENT
DEVICE
104
TYPE
D
1208
TYPE
B
1210
TYPE
B
CANNOT
READ
1211

FIG. 13

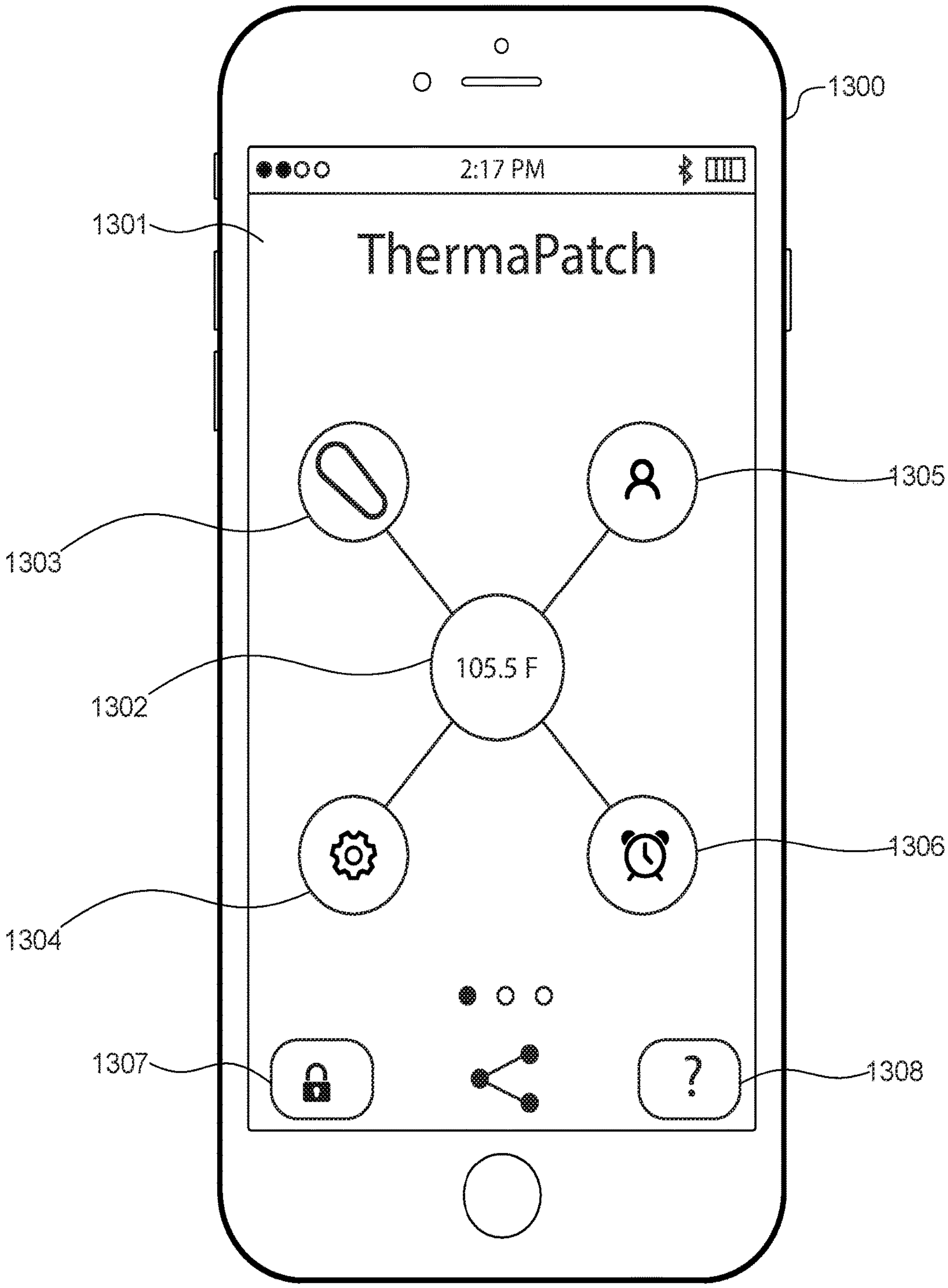

1300
2:17 PM
1301
ThermaPatch
1305
1303
1302
105.5 F
1306
1304
1307
?
1308

FIG. 14

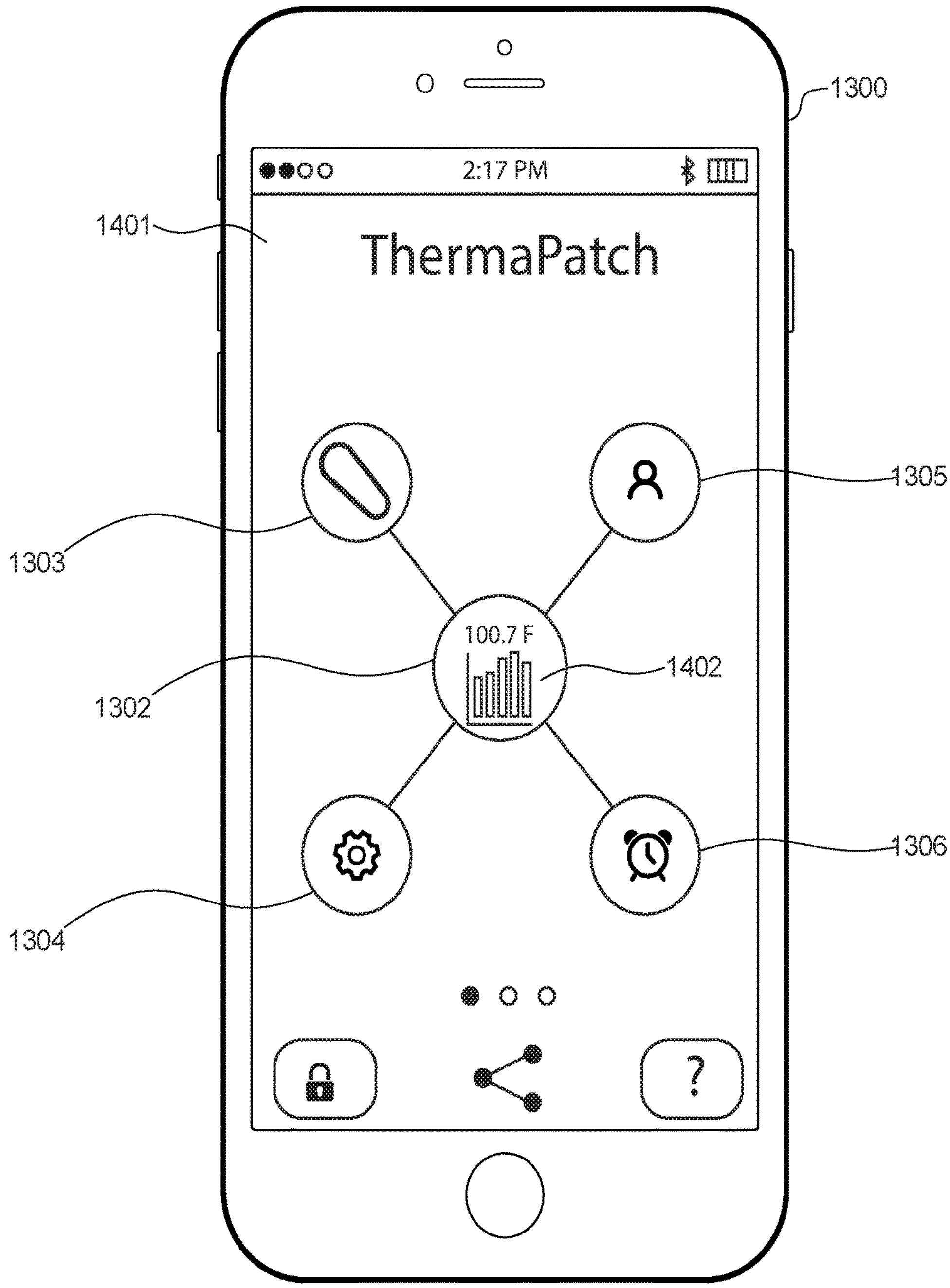

1300
2:17 PM
1401
ThermaPatch
1305
1303
100.7 F
1402
1302
1306
1304
?

FIG. 15

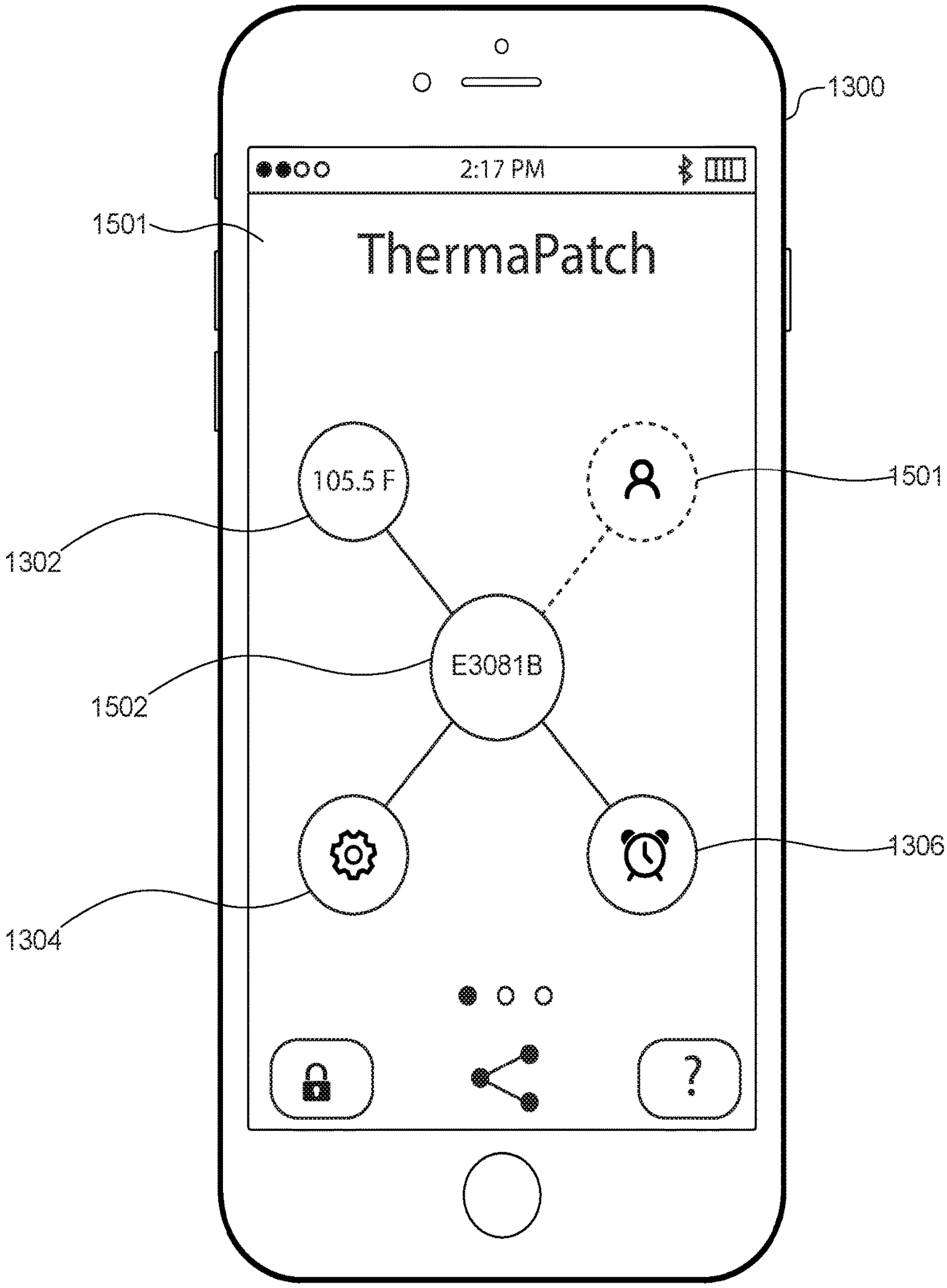

1300
2:17 PM
1501
ThermaPatch
105.5 F
1501
1302
E3081B
1502
1306
1304
?

FIG. 16

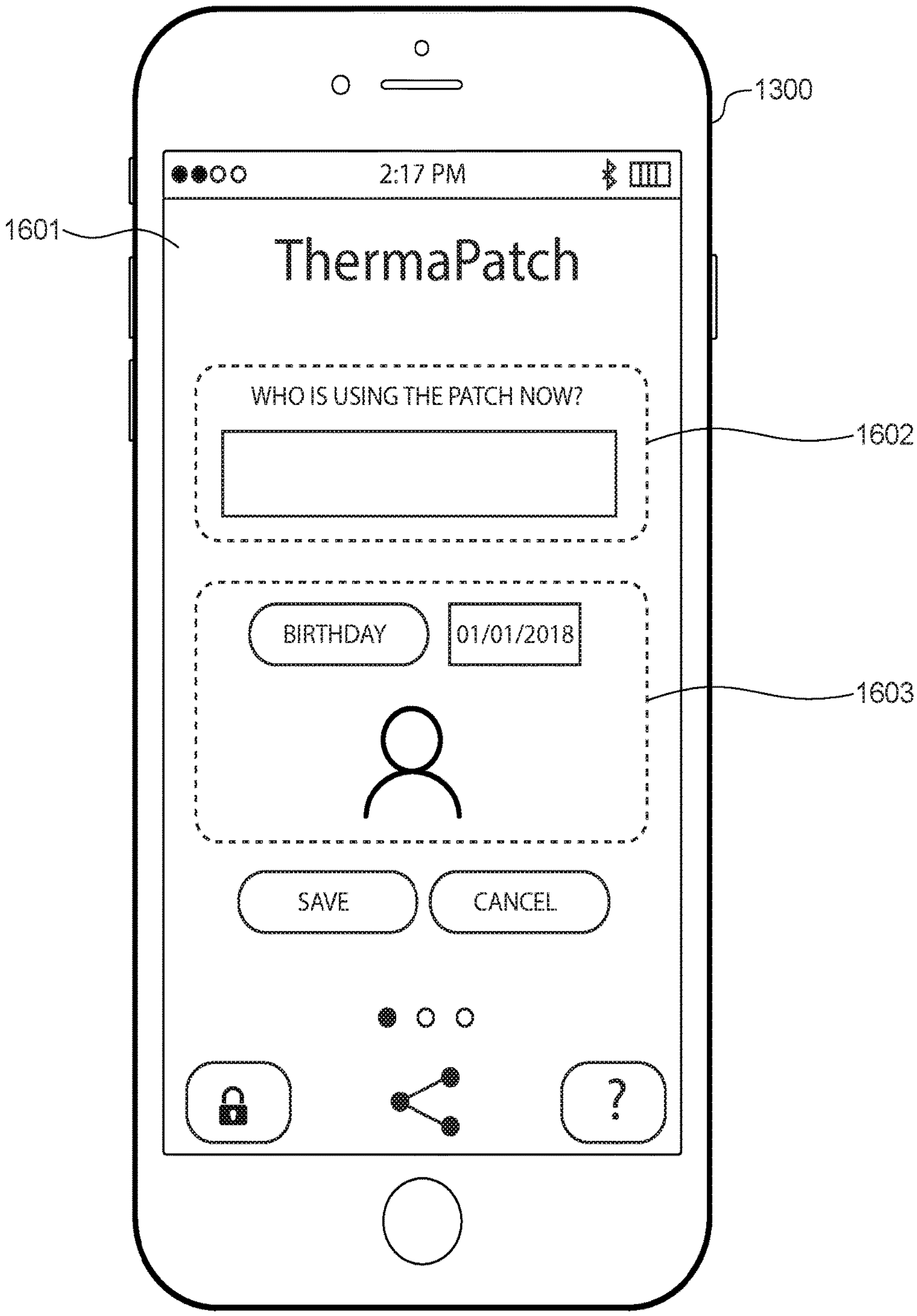

1300
1601
2:17 PM
ThermaPatch
WHO IS USING THE PATCH NOW?
1602
BIRTHDAY
01/01/2018
1603
SAVE
CANCEL
?

FIG. 17

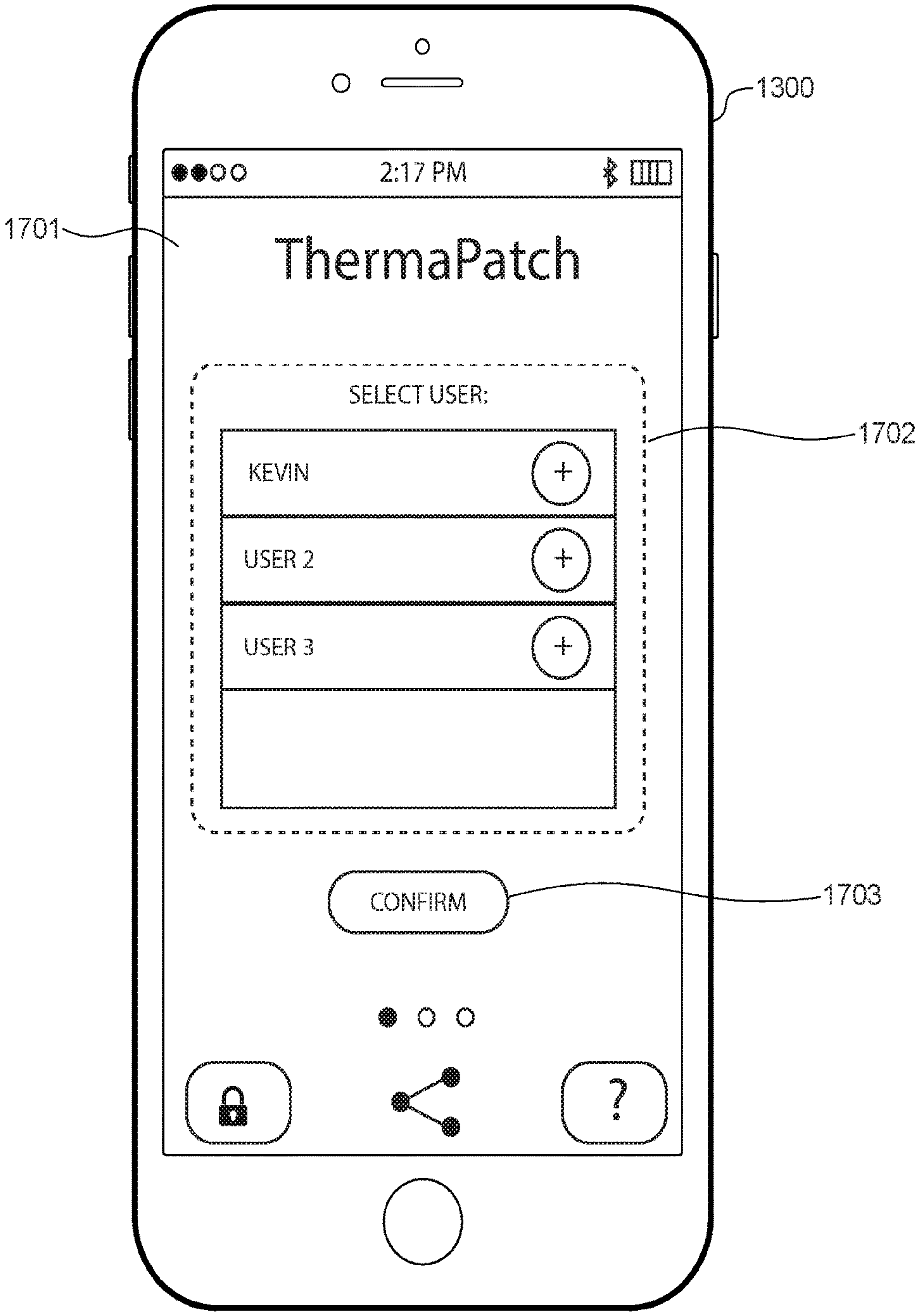

1300
2:17 PM
1701
ThermaPatch
SELECT USER:
1702
KEVIN
USER 2
USER 3
CONFIRM
1703
?

FIG. 18

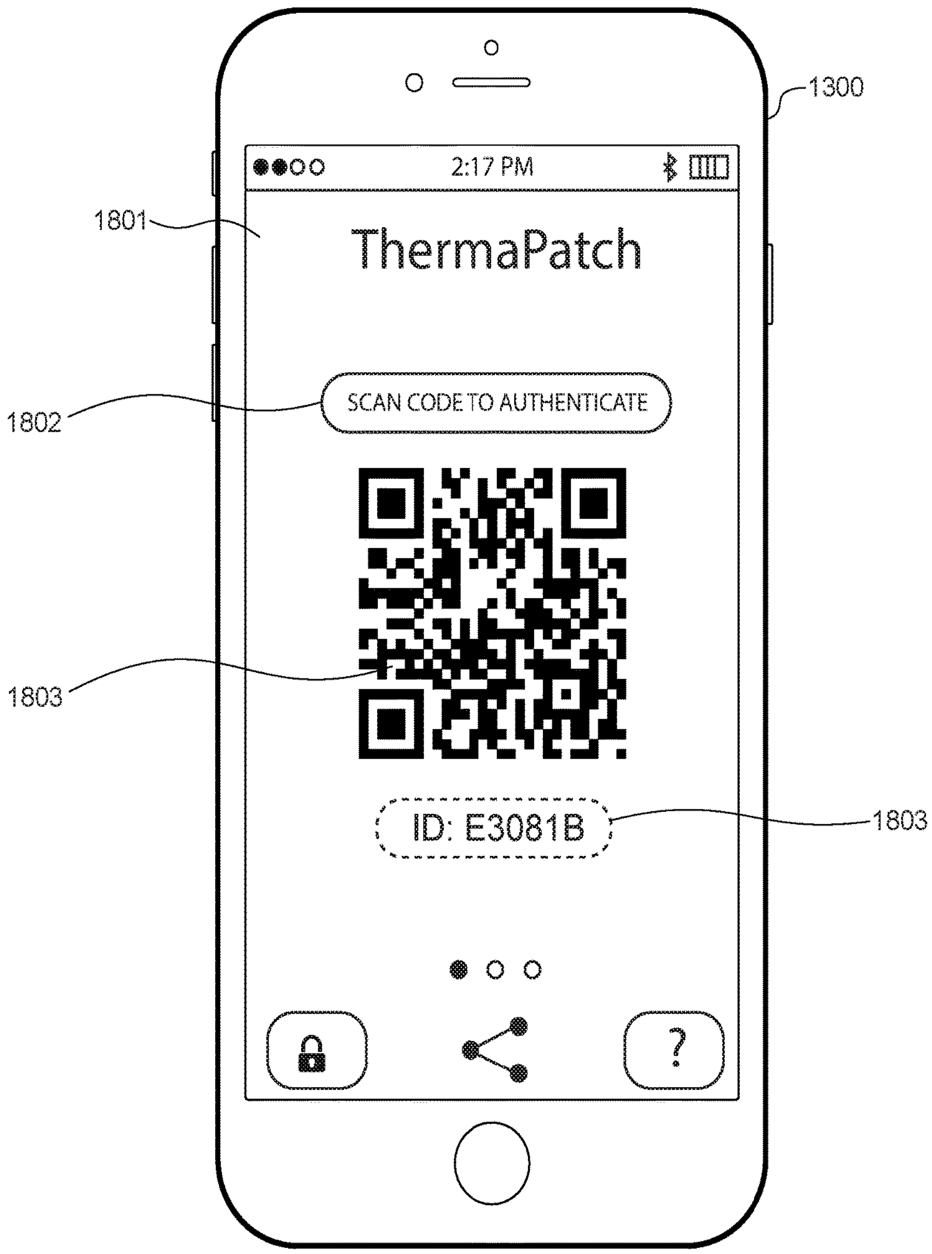

1300
1801
2:17 PM
ThermaPatch
1802
SCAN CODE TO AUTHENTICATE
1803
ID: E3081B
1803
?

FIG. 19

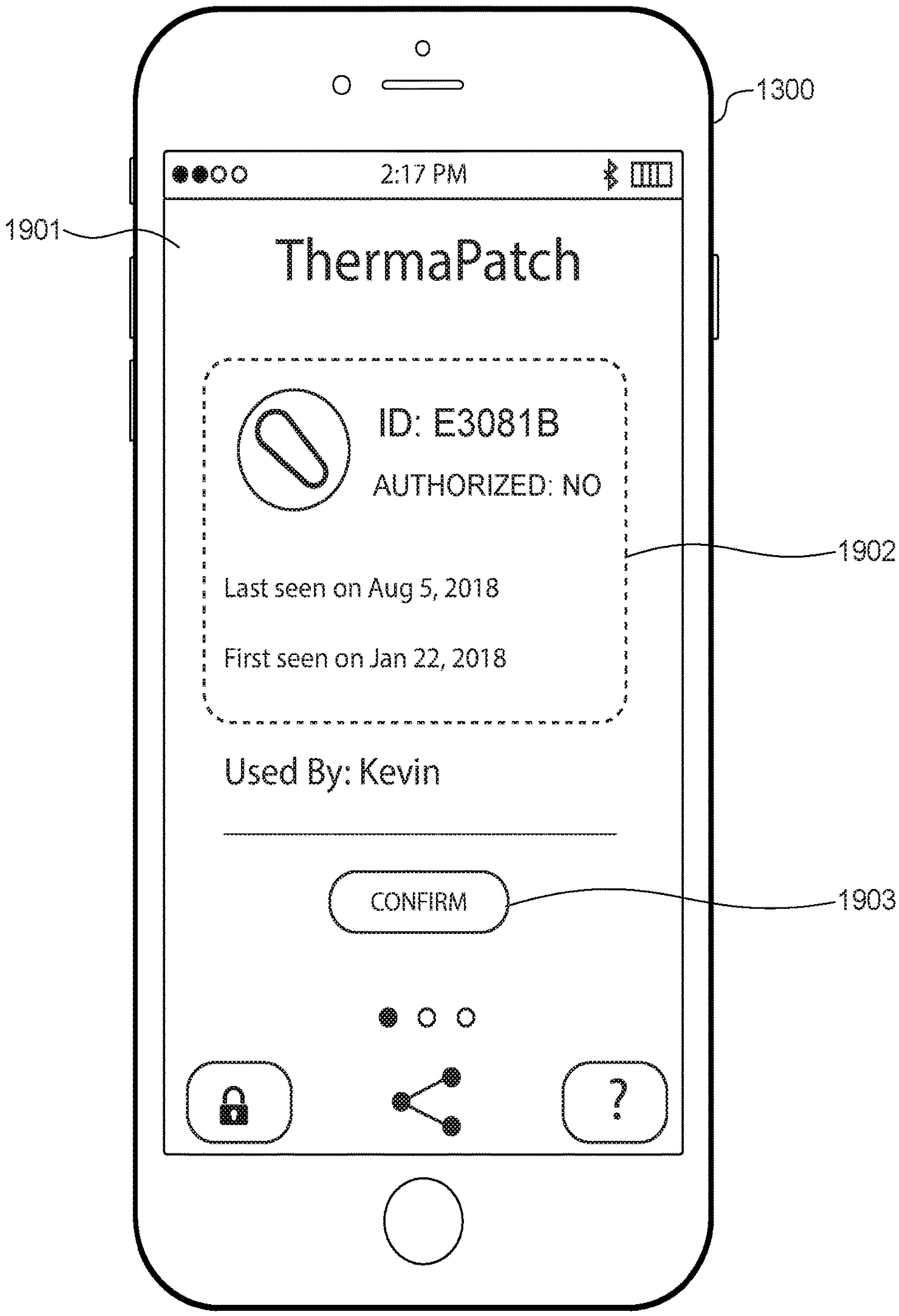

1300
1901
2:17 PM
ThermaPatch
ID: E3081B
AUTHORIZED: NO
Last seen on Aug 5, 2018
First seen on Jan 22, 2018
1902
Used By: Kevin
CONFIRM
1903
?

FIG. 20

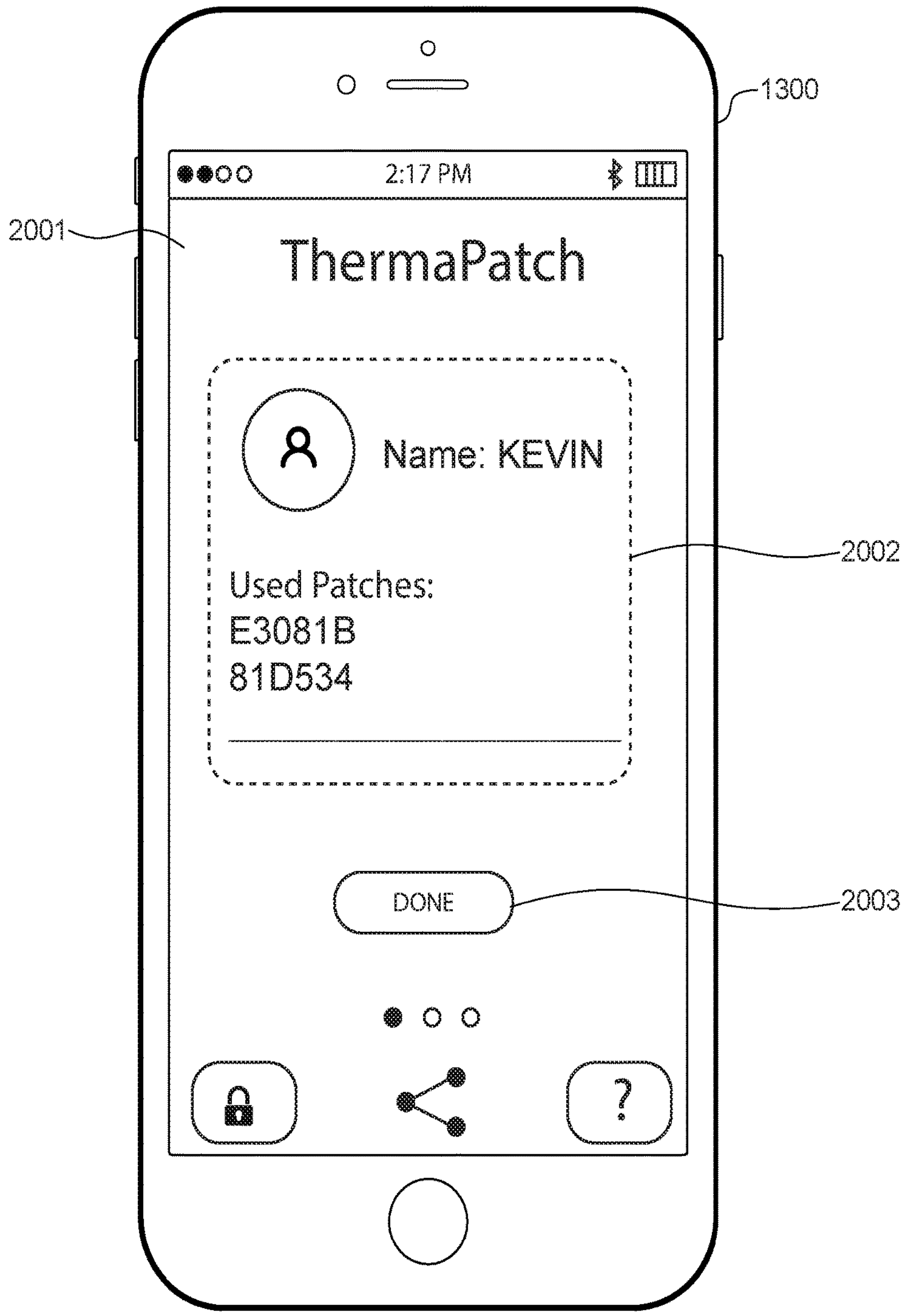

1300
2:17 PM
2001
ThermaPatch
Name: KEVIN
2002
Used Patches:
E3081B
81D534
DONE
2003
?

FIG. 21

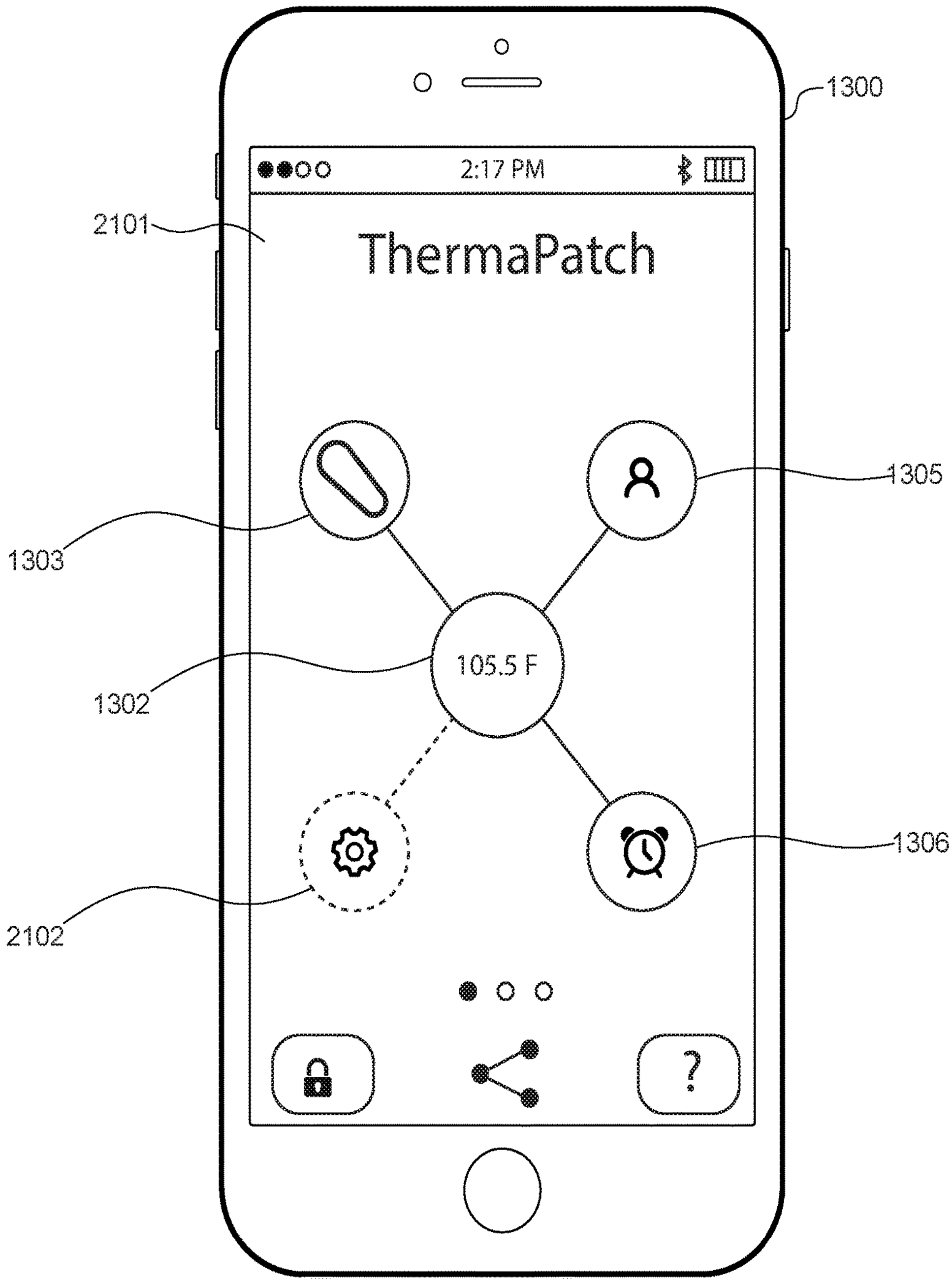


FIG. 22

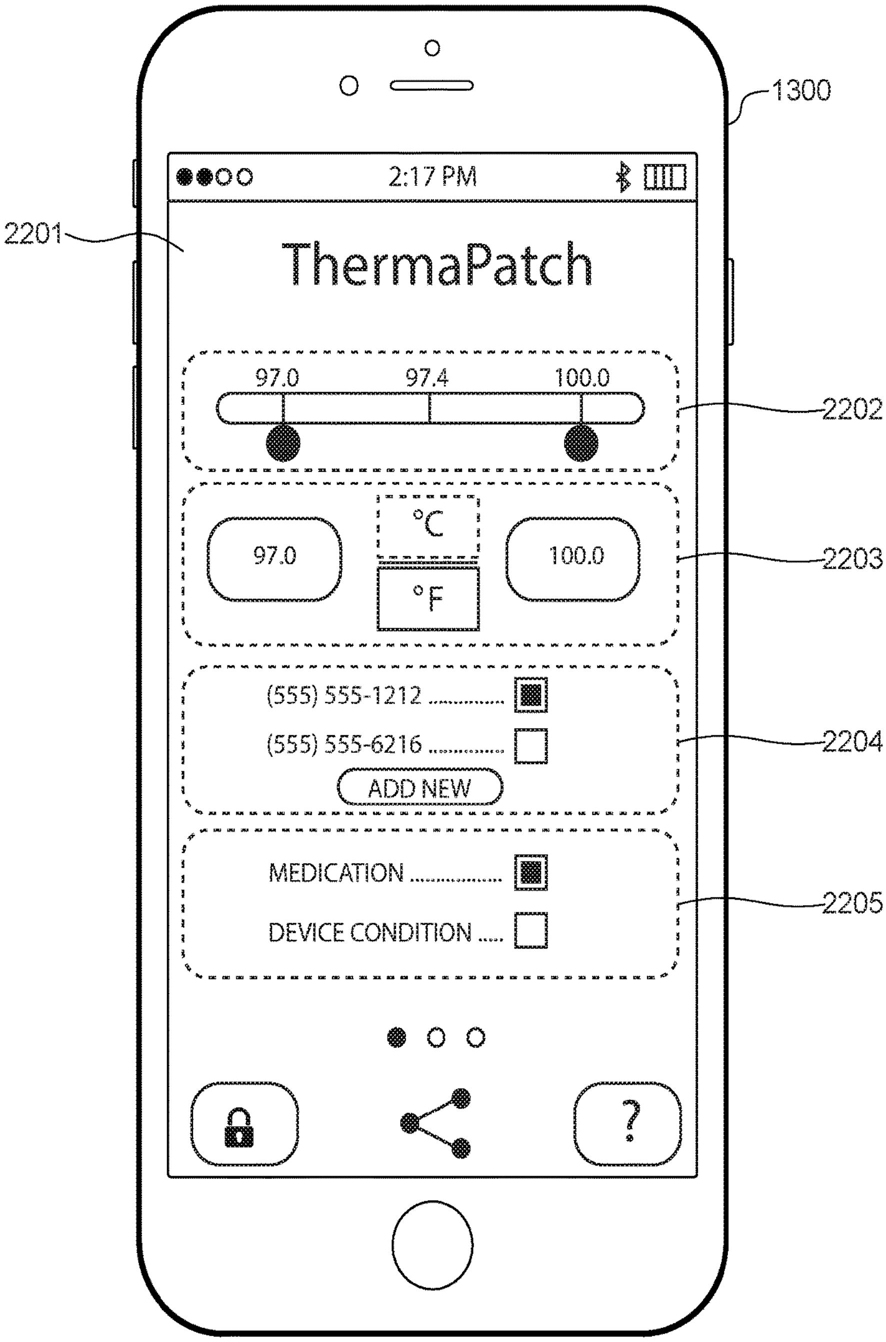

1300
2201
2:17 PM
ThermaPatch
97.0
97.4
100.0
2202
°C
97.0
100.0
°F
2203
(555) 555-1212
(555) 555-6216
ADD NEW
2204
MEDICATION
DEVICE CONDITION
2205
?

FIG. 23

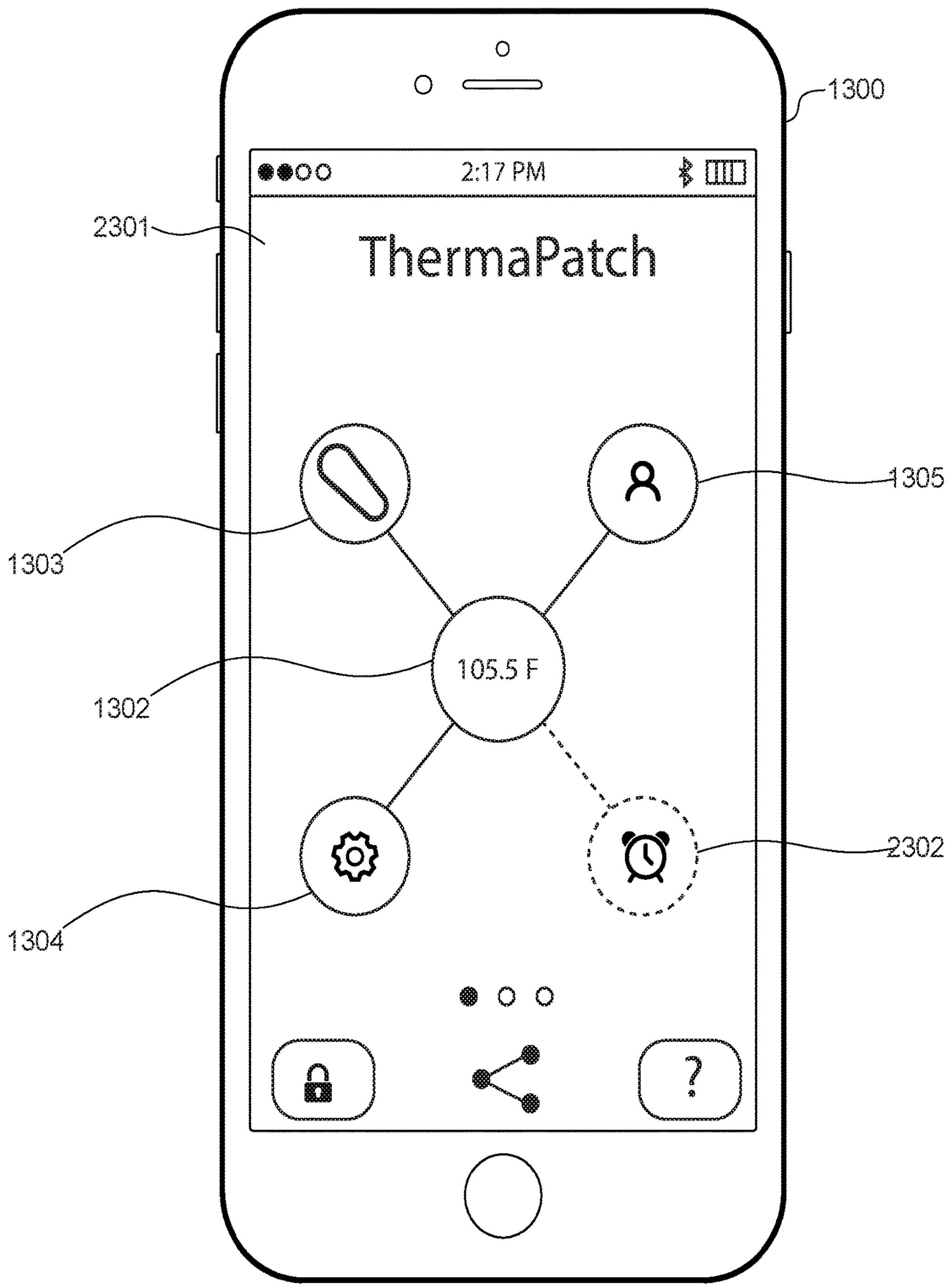
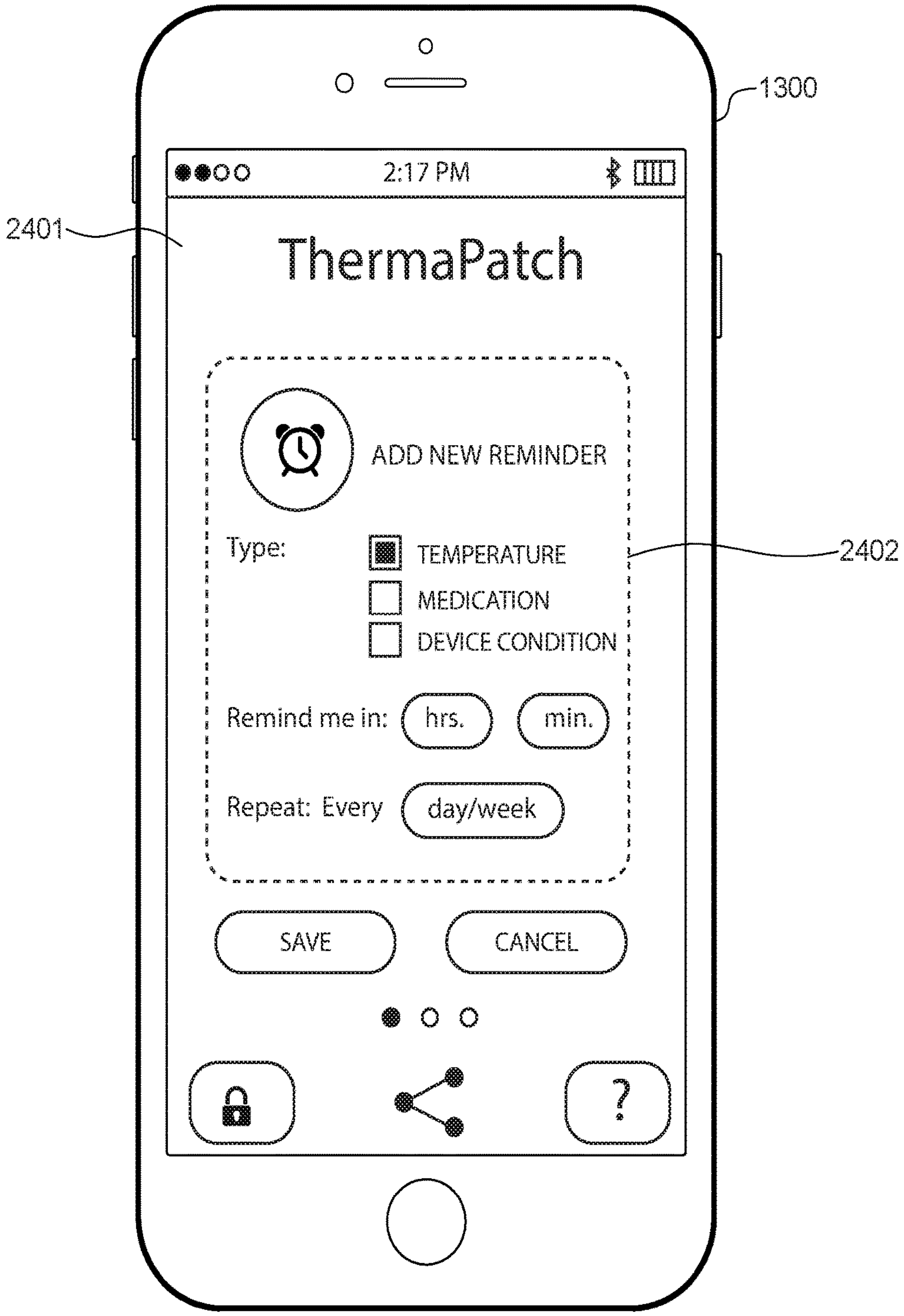


FIG. 24



1300
2401
2:17 PM
ThermaPatch
ADD NEW REMINDER
Type:
TEMPERATURE
MEDICATION
DEVICE CONDITION
2402
Remind me in:
hrs.
min.
Repeat: Every
day/week
SAVE
CANCEL
?

FIG. 25

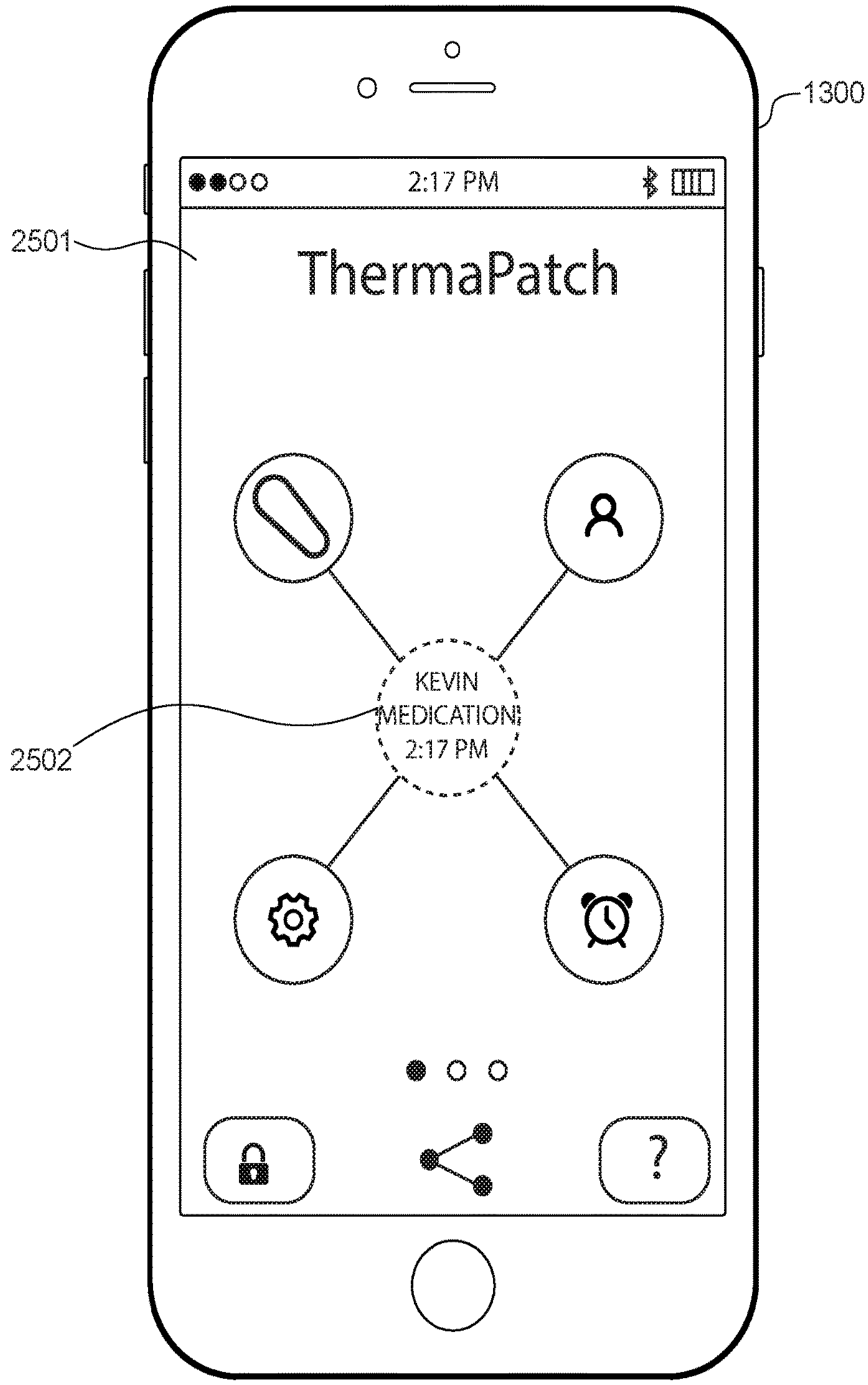


FIG. 26

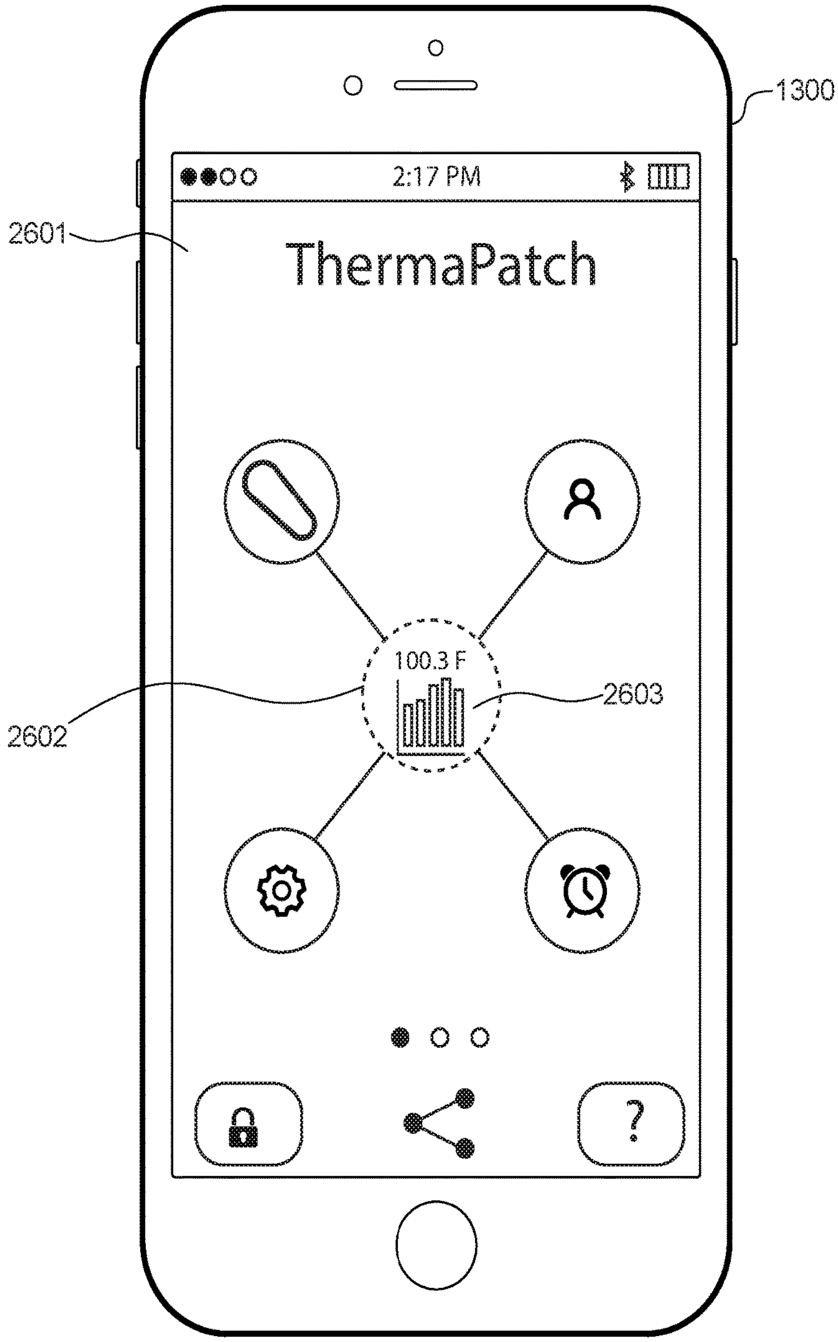


FIG. 27

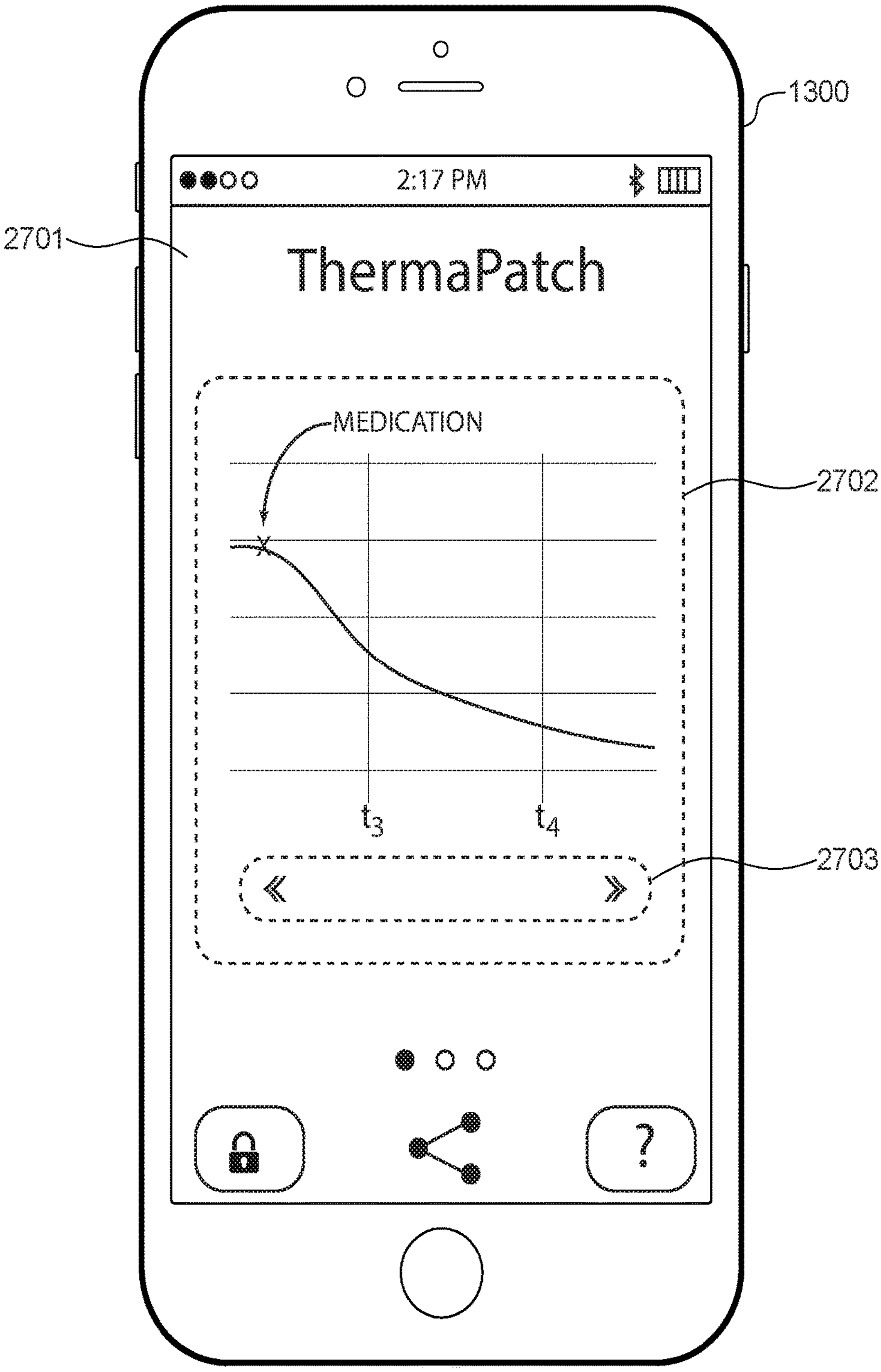


FIG. 28

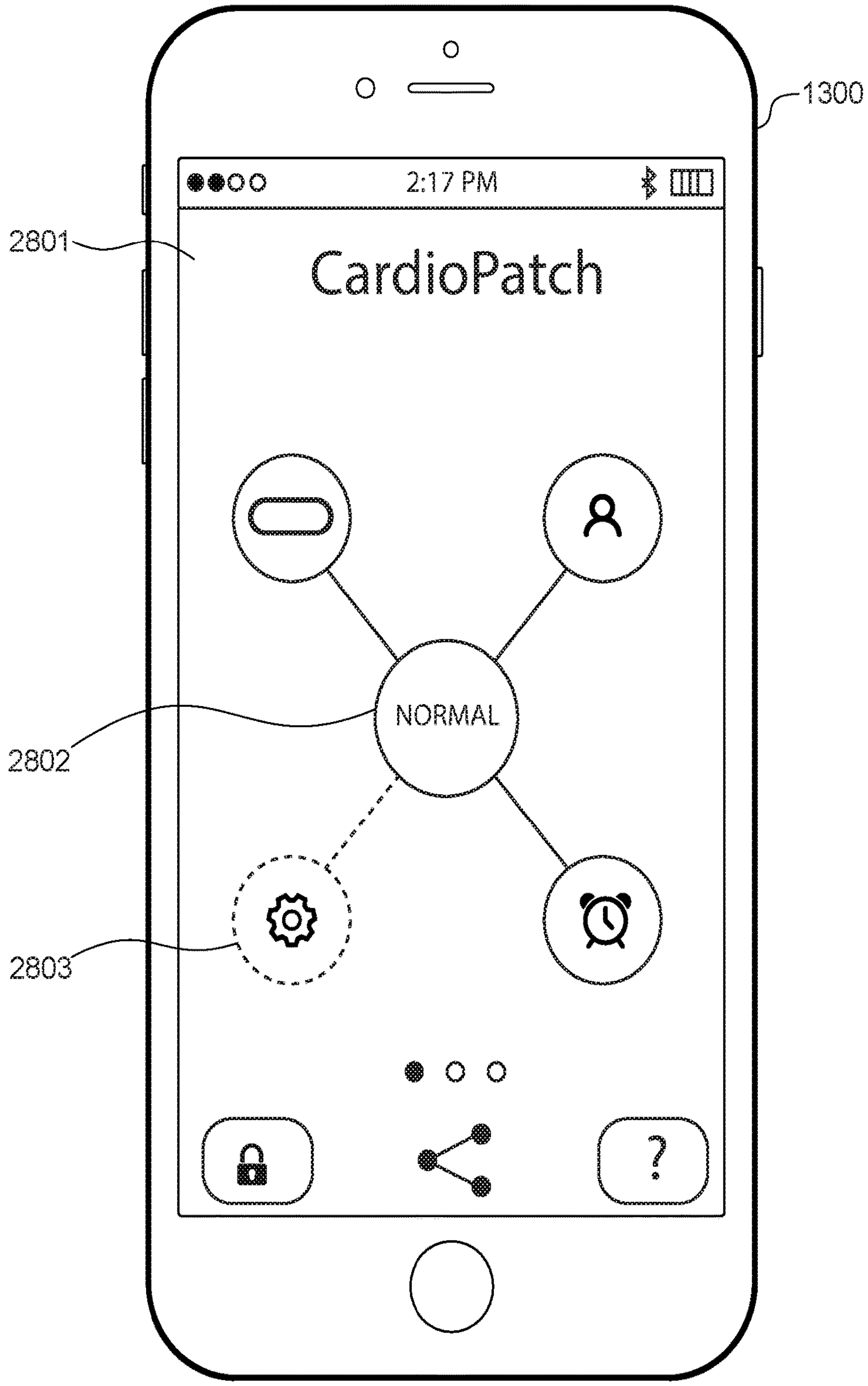
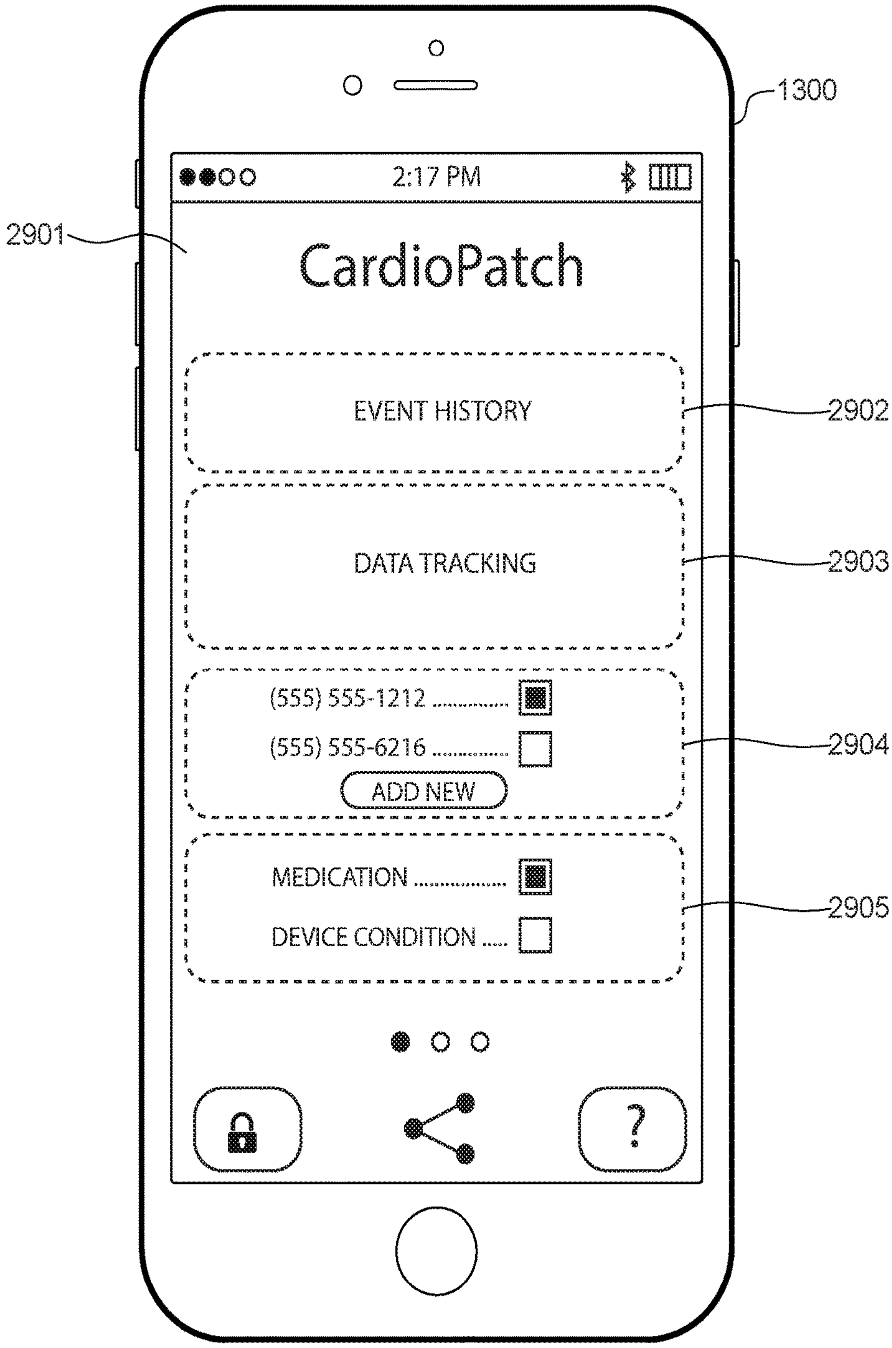


FIG. 29


1300
2:17 PM
2901
CardioPatch
EVENT HISTORY
2902
DATA TRACKING
2903
(555) 555-1212
(555) 555-6216
ADD NEW
2904
MEDICATION
DEVICE CONDITION
2905
?

SYSTEM AND METHOD OF CONTINUOUS HEALTH MONITORING

PRIORITY NOTICE

[0001] The present application claims priority under 35 U.S.C. § 119 to U.S. Provisional Application 62/558,995, filed Sep. 15, 2017, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD OF THE INVENTION

[0002] The present invention relates in general to a system and method of continuous health monitoring, and more specifically, to continuous health monitoring using a wearable device that wirelessly communicates electrical activity, which may be in conjunction with improved temperature readings, to one or more client devices.

COPYRIGHT AND TRADEMARK NOTICE

BACKGROUND OF THE INVENTION

[0005] Health monitoring of individuals using wearable devices is becoming a widespread practice. The prior art is beginning to see more and more wearables that can monitor and track different metrics such as how many steps a user takes during the day, what their approximate heart rate is at a given time, etc. Other metrics are more difficult to read with popular devices such as the smart watches and fitness bands of today. For example, many smart watches and fitness bands fail to include hardware that reads certain critical vital signs—like body temperature.

[0006] Reading the body's core temperature accurately is not easily achieved by placing a sensor in just any area of the human body; for example, a smart watch equipped with a temperature sensor for example is unlikely to properly read a user's body core temperature because the wrist is not a medically recognized region for accurately taking temperature measurements—accordingly, any reading of temperature may simply be undependable with common wearables.

[0007] However, there have been some developments in the continuous monitoring of the body's core temperature; several wireless solutions exist that consist of a wearable device configured to monitor the temperature of a user, which can connect to a smartphone or tablet for reception of temperature data. Some of these newer devices attempt to monitor skin temperature in the armpit or axillary region where there is medical acceptance. Yet, these devices are riddled with shortcomings.

[0008] One persistent problem in body-worn wearable devices is the design and placement of antennas. For example, some devices, designed to be placed at the axillary region, fail in function because the axillary region is an enclosed cavity surrounded by body tissue that severely attenuates radio frequency signal, thereby rendering the device unable to properly transmit the temperature measured to a listening device. Thus, it is desirable to have a device with an appropriately designed antenna suitable for overcoming signal transmission challenges related to the human anatomy.

[0009] Another problem is the delay in getting an accurate measurement of body temperature after applying the device on the body. Any measurement means that uses a temperature sensor suffers latency that comes from having to get the temperature sensor in thermal equilibrium with the body—usually causing a delay in the order of minutes. This delay is not acceptable to users who are looking for an accurate reading in seconds. Part of the problem resides in the material and means used for conducting heat. The devices disclosed in U.S. Patent Application 2016/0183794 to Gannon et al, for example, suffers from the shortcomings mentioned above. Thus, it is desirable to minimize the latency in a continuous monitoring device so that information may be gleaned quickly and acted upon as needed.

[0010] Yet another problem is providing proper battery life suitable for effective continuous health care monitoring; battery life is a challenge for wearable devices and has not been adequately addressed. Many wearable devices now use Bluetooth Low-Energy (BLE) to lower the power consumed over the communications link. The power consumed by these devices is still too high to allow wearable devices to last for many months without recharging or without using a large and intrusive primary battery. For a wearable device that is meant to be used for continuous monitoring, recharging is a problem because the time taken for recharging keeps the device from being used for monitoring. The problem gets worse for a device that is designed to monitor and act continuously such as in delivering a continuous dose of medication; these devices can't be allowed to take time off for recharging. The ideal solution is a device that can be used without recharging for as long as possible, wherein the lifetime of the product becomes its differentiating feature.

[0011] One factor in power consumption is the power consumed by communication of data from the wearable device. US Patent Application 2016/0095047 to Lee et al. and U.S. Pat. No. 8,208,973 to Mehta address the problem by implementation of various time intervals for multiple different advertising packets or in different operating modes. However, as will be explained below, certain battery parameters are not fully factored by the methods in these disclosures, which may be useful in determination of time intervals for advertising packets or the contents of the packets so as to further increase power efficiency and generally prolong battery life of wearable devices.

[0012] Yet another problem is keeping data provided by these devices adequately secure. A medical device should be designed to provide privacy of patient data over communication and storage. Typically, wireless medical devices transfer patient data to a single device over a dedicated connection, or broadcast patient data to any device that is within listening range. The former approach restricts the use of the monitoring solution to only one user, which can be a single point of failure when the monitoring device is out of range or powered down. The latter approach of data broadcast is more reliable as the broadcasts can be received by several monitoring devices that are in range; but as the data is transmitted on the broadcast channel, patient data is no longer private. To ensure secure transmission over a wireless communication system, patient data requires additional encryption not provided by transmission protocols over a broadcast channel. To encrypt patient data, encryption keys have to be shared between the medical device and the device receiving the patient data, and it is known that these encryption keys may be intercepted. U.S. Pat. No. 8,130,958 to Schrum and US Patent Application 2002/0123325A1 to Cooper address the problem by reducing transmission power so that proximity is required between the two devices that are communicating with each other. The limitations of these two approaches is that even at lowest power settings, a receiver dedicated to eavesdropping on a channel can do so from several feet. Thus, it is necessary for a medical device to protect user data from unauthorized access by storing and transmitting data securely; although several solutions have been disclosed, the problem has not been adequately addressed.

[0013] Yet another problem that has not been adequately addressed is providing timely insights and providing these insights via meaningful alerts to the right entities. A key aspect of health monitoring is alerting to detected changes in the condition of the user and the condition of the monitoring device. Certain insights need to be communicated to the user or an authorized person as soon as possible. An example may include detection of low-grade fever, which typically only the user or the caregiver may need to be made aware. However, when fever in cancer patients exceeds a certain threshold, it is often necessary to have the patient's clinic or emergency room be advised of the developing condition. Thus, it is desirable that a system of a wearable device generate proper insights and implement adequate notifications.

[0014] Yet another problem faced by wearables is the device's adaptability to the wearer's environment. Wearable devices for continuous monitoring may be worn all the time, but there are times when these devices should be put in a non-transmitting mode even when worn. For example, this is true when users are passing through security checks or when they are flying on an airplane. Thus, it is desirable that a wearable device be made adaptable to different environmental conditions.

[0015] Therefore, there exists a previously unappreciated need for a new and improved system and method of continuous health monitoring that: is suitable for overcoming certain signal transmission challenges; minimizes latency so that information may be gleaned and acted upon quickly as needed; increases efficiency and generally prolongs battery life of the wearable device; protects user data from unauthorized access by storing and transmitting data securely; may be easily adapted for different environmental conditions; and is configured to generate proper insights and implement adequate notifications concerning the user.

[0016] It is to these ends that the present invention has been developed.

SUMMARY OF THE INVENTION

[0017] To minimize the limitations in the prior art, and to minimize other limitations that will be apparent upon reading and understanding the present specification, the present invention describes a system and method of continuous health monitoring, which implements a wearable device that wirelessly communicates improved temperature readings to one or more client devices.

[0018] Generally, the invention involves a system comprising at least one wearable device that employs a flexible printed circuit board (PCB), which includes a temperature sensor. The flexible PCB may be printed on a flexible substrate that may be folded to form multiple layers configured to house the sensor and an antenna. The sensor may be housed within said layers and situated at a terminal end of a pathway that may be printed on the PCB, which conducts heat from the body of the user to the sensor. The antenna may be housed within the layers of the flexible PCB in a manner such that proper signal transmission is preserved, and latency is minimized. A part of the flexible PCB may be folded around a battery to connect to the terminals of the battery. Temperature readings may be wirelessly communicated to one or more client devices, which implement one or more algorithms suitable for generating insights regarding one or more health aspects of the user. The system may also further comprise another wearable device suitable for reading multiple voltage differentials throughout the human body of a user. In exemplary embodiments, such wearable device may comprise a plurality of contacts, some of which may be applied directly to the body and some of which may be disposed on a surface of the device for a user to interact with. A multiplexer in communication with a microprocessor housed within the wearable device may be used to receive and process the voltage differences; a communications module may transmit the voltage differentials to one or more client devices. As may be appreciated, these signals pertaining to voltage differentials throughout the body may be utilized to detect abnormalities indicative of a health condition, and or used for monitoring the health of the user. In certain embodiments, the voltage differentials may be used to measure the electrocardiogram (ECG or EKG) of the user so as to determine the cardiac health of the user, the detection of which can lead to timely intervention for ischemia, fibrillation, arrhythmia, tachycardia or any other heart condition that is detectable using ECG. In certain other embodiments, the voltage differentials may be used to measure neural activity to detect the onset of seizures and the detection of epilepsy, and to provide feedback on an autistic user's ability to learn. In exemplary embodiments, a feedback module may be incorporated such as a haptic device to alert the user in the event an anomaly in the voltage differential is detected. As may be appreciated by a person of skill in the medical field, such wearable device has many applications, including but not limited to, monitoring a cardiovascular health of the user. In some exemplary embodiments, one or more of the wearable devices communicate user data to a client device such as a smartphone. In some exemplary embodiments, one or more of the wearable devices further communicate data to a server. In some exemplary embodiments, the server may host a user interface such as a website or mobile application so that one or more users may access the user data remotely.

[0019] Moreover, several methods may be implemented to: determine body core temperature; determine basal body temperature; measure, communicate and alert of physical parameters of human body such as axillary temperature to monitor fever or to detect the basal body temperature that forms the basis for ovulation monitoring or hormonal deficiency; provide one or more insights concerning health aspects of a user; determine a wearable device state; prolong battery life; and maintain secured user data for patient privacy and reliability of communication of said data.

[0020] A wearable device, in accordance with an exemplary embodiment of the present invention, comprises: a flexible printed circuit board (PCB) that may be folded to form multiple layers; a temperature sensor situated on a first surface of a first layer of the PCB; a circuit including a copper contact region etched on a second surface of the first layer of the PCB, the copper circuit including one or more copper pathways connecting the thermal contact region of the copper circuit to the temperature sensor; a communication transmitter including an antenna situated on one of the multiple layers of the PCB; and a microprocessor in communication with the temperature sensor and the communication transmitter, the microprocessor configured to continuously obtain temperature sensing data from the temperature sensor and transmit the sensing data to one or more client devices.

[0021] A system for continuous health monitoring, in accordance with an exemplary embodiment of the present invention, comprises: a server for storing health data including temperature data; a wearable device including: a flexible printed circuit board (PCB) that is folded to form multiple layers; a temperature sensor situated on a first surface of a first layer of the PCB; a circuit including a thermal contact region etched on a second surface of the first layer of the PCB, the circuit including one or more pathways connecting the contact region of the circuit to the temperature sensor; a communication transmitter including an antenna situated on one of the multiple layers of the PCB; and a microprocessor in communication with the temperature sensor and the communication transmitter, the microprocessor configured to: continuously obtain temperature sensing data from the temperature sensor; and transmit the sensing data to one or more client devices; and a user interface executable by one of the one or more client devices configured to display information associated with the temperature sensing data.

[0022] A method in accordance with practice of an exemplary embodiment of the present invention, comprises: A method of continuous health monitoring implemented by a wearable device, comprising: receiving temperature data from one or more sensors on a flexible printed circuit board (PCB) that is folded to form multiple layers, wherein the one or more temperature sensors are situated on a first surface of a first layer of the PCB, including a copper circuit for transferring heat from a copper thermal contact etched on a second surface of the first layer of the PCB, the copper circuit including one or more copper pathways connecting the copper contact of the copper circuit to the temperature sensor; generating one or more data packets associated with the temperature data; and sending via a communication transmitter including an antenna situated on one of the multiple layers of the PCB, the one or more data packets associated with the temperature data to a client device.

[0023] Various objects and advantages of the present invention will become apparent from the following description taken in conjunction with the accompanying drawings wherein are set forth, by way of illustration and example, certain embodiments of this invention. The drawings submitted herewith constitute a part of this specification, include exemplary embodiments of the present invention, and illustrate various objects and features thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Elements in the figures have not necessarily been drawn to scale in order to enhance their clarity and improve understanding of the various embodiments of the invention. Furthermore, elements that are known to be common and well understood to those in the industry are not depicted in order to provide a clear view of the various embodiments of the invention. The drawings that accompany the detailed description can be briefly described as follows:

[0025] FIG. **1**(*a*) illustrates a system in accordance with an exemplary embodiment of the present invention.

[0026] FIG. **1**(*b*) illustrates a diagram of a wearable device in accordance with an exemplary embodiment of the present invention.

[0027] FIG. **2**(*a*) depicts a bottom view of a flexible PCB for a wearable device in accordance with an exemplary embodiment of the present invention.

[0028] FIG. **2**(*b*) depicts a top view of a flexible PCB for a wearable device in accordance with an exemplary embodiment of the present invention.

[0029] FIG. **2**(*c*) depicts a flexible PCB partially coupled to a plastic layer in accordance with an exemplary embodiment of the present invention.

[0030] FIG. **2**(*d*) depicts a top view of the flexible PCB partially folded over the foam layer depicted in FIG. **2**(*c*).

[0031] FIG. **2**(*e*) depicts a bottom view of the flexible PCB partially folded over and threaded through a portion of the foam layer depicted in FIG. **2**(*a*).

[0032] FIG. **3**(*a*) depicts a bottom view of a flexible PCB for a wearable device in accordance with an exemplary embodiment of the present invention.

[0033] FIG. **3**(*b*) depicts a top view of a flexible PCB for a wearable device in accordance with an exemplary embodiment of the present invention.

[0034] FIG. **3**(*c*) depicts an exploded view of the flexible PCB depicted in FIG. **3**(*a*)-(*b*), including a housing in accordance with an exemplary embodiment of the present invention.

[0035] FIG. **3**(*d*) depicts a top view of the flexible PCB depicted in FIG. **3**(*a*)-(*b*), placed inside a first portion of the housing depicted in FIG. **3**(*c*).

[0036] FIG. **3**(*e*) depicts a bottom view of the flexible PCB depicted in FIG. **3**(*a*)-(*b*), placed inside a second portion of the housing depicted in FIG. **3**(*c*).

[0037] FIG. **3**(*f*)-**3**(*h*) depict the wearable device fully enclosed in the housing depicted in FIG. **3**(*c*).

[0038] FIG. **3**(*i*) depicts an exploded view of the flexible PCB depicted in FIG. **3**(*a*)-(*b*), including a housing in accordance with an exemplary embodiment of the present invention.

[0039] FIG. **3**(*j*) depicts a top view of the flexible PCB depicted in FIG. **3**(*a*)-(*b*), placed inside a first portion of the housing depicted in FIG. **3**(*i*).

[0040] FIG. **3**(*k*) depicts a bottom view of the flexible PCB depicted in FIG. **3**(*a*)-(*b*), placed inside a second portion of the housing depicted in FIG. **3**(*i*).

[0041] FIG. **4**(*a*) illustrates different folds of the PCB within layers of the device in accordance with an exemplary embodiment of the present invention.

[0042] FIG. **4**(*b*) illustrates a side view of a folded PCB and different layers formed therein in accordance with an exemplary embodiment of the present invention.

[0043] FIG. **4**(*c*) illustrates a sensor and heat pathway of an exemplary PCB in accordance with the present invention.

[0044] FIG. **4**(*d*) illustrates a close-up view of an exemplary embodiment of a flexible PCB and foam configuration in accordance with the present invention.

[0045] FIG. **5**(*a*) illustrates a flow chart of an exemplary method of reading electrical activity, which may be in conjunction with temperature data in accordance an exemplary embodiment of the present invention.

[0046] FIG. **5**(*b*) illustrates a block diagram of a wearable device including multiple electrically-conducting contacts and does not necessarily include a temperature sensor, this wearable device configured to generate voltage differentials pertaining to a user, in accordance with exemplary embodiments of the present invention.

[0047] FIG. **5**(*c*) and FIG. **5**(*d*) illustrate an enclosure or housing for the exemplary wearable device depicted in the block diagram of FIG. **5**(*b*).

[0048] FIG. **5**(*e*) is a flow chart depicting an exemplary method employed by an exemplary embodiment of the wearable device illustrated in FIG. **5**(*b*)-FIG. **5**(*c*).

[0049] FIG. **6** is a flow chart depicting an exemplary method of deriving basal body temperature in exemplary practice of an embodiment of the present invention.

[0050] FIG. **7**(*a*) is a chart showing temperature as a function of time, which demonstrates a method for determining different device states in exemplary practice of an embodiment of the present invention.

[0051] FIG. **7**(*b*) is a flow chart depicting an exemplary method of deriving and presenting insights to a user in exemplary practice of an embodiment of the present invention.

[0052] FIG. **7**(*c*) is a chart showing temperature as a function of time, which demonstrates a method of deriving useful insights in exemplary practice of an embodiment of the present invention.

[0053] FIG. **8** is a flow chart depicting an exemplary method of throttling data in exemplary practice of an embodiment of the present invention.

[0054] FIG. **9** is a flow chart depicting an exemplary processing flow of typical programmable instructions on a wearable device in accordance with the present invention.

[0055] FIG. **10** is a flow chart depicting an exemplary method of communicating user data between a wearable device and a client device in exemplary practice of an embodiment of the present invention.

[0056] FIG. **11** is a flow chart depicting an exemplary method of authorizing one or more devices to read data captured by a wearable device in exemplary practice of an embodiment of the present invention.

[0057] FIG. **12** is a flow chart depicting an exemplary method of authorizing one or more devices to read data captured by a wearable device in exemplary practice of an embodiment of the present invention.

[0058] FIG. **13**-FIG. **29** illustrate an exemplary user interface that may be distributed to a plurality of client devices in accordance with exemplary embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0059] In the following discussion that addresses a number of embodiments and applications of the present invention, reference is made to the accompanying drawings that form a part thereof, where depictions are made, by way of illustration, of specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and changes may be made without departing from the scope of the invention. Wherever possible, the same reference numbers are used in the drawings and the following description to refer to the same or similar elements.

[0060] Conditional language used herein, such as, among others, "can," "could," "might," "may," "e.g.," and the like, unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without author input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular embodiment.

[0061] The terms "comprising," "including," "having," and the like are synonymous and are used inclusively, in an open-ended fashion, and do not exclude additional elements, features, acts, operations and so forth. Also, the term "or" is used in its inclusive sense (and not in its exclusive sense) so that when used, for example, to connect a list of elements, the term "or" means one, some, or all of the elements in the list. Conjunctive language such as the phrase "at least one of X, Y, and Z," unless specifically stated otherwise, is otherwise understood with the context as used in general to convey that an item, term, etc. may be either X, Y, or Z. Thus, such conjunctive language is not generally intended to imply that certain embodiments require at least one of X, at least one of Y, and at least one of Z to each be present. The term "and/or" means that "and" applies to some embodiments and "or" applies to some embodiments. Thus, A, B, and/or C can be replaced with A, B, and C written in one sentence and A, B, or C written in another sentence. A, B, and/or C means that some embodiments can include A and B, some embodiments can include A and C, some embodiments can include B and C, some embodiments can only include A, some embodiments can include only B, some embodiments can include only C, and some embodiments include A, B, and C. The term "and/or" is used to avoid unnecessary redundancy.

[0062] While embodiments of the disclosure may be described, modifications, adaptations, and other implementations are possible. For example, substitutions, additions, or modifications may be made to the elements illustrated in the drawings, and the methods described herein may be modified by substituting, reordering, or adding stages to the disclosed methods. Thus, nothing in the foregoing description is intended to imply that any particular feature, characteristic, step, module, or block is necessary or indispensable. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions, and changes in the form of the methods and systems described herein may be made without departing from the spirit of the inventions disclosed herein. Accordingly, the following detailed description does not limit the disclosure. Instead, the proper scope of the disclosure is defined by the appended claims.

[0063] Turning now to the figures, FIG. **1**(*a*) illustrates a system in accordance with an exemplary embodiment of the present invention. More specifically, FIG. **1**(*a*) shows system **100**, which comprises: wearable device **101** including a processing unit for executing programmable instructions **102** concerning sensor readings of one or more sensors of wearable device **101**; and client devices **103** and **104**, wherein client device **103** may include software or application **103***a* suitable to read and display to a user sensing data transmitted by wearable device **101**. Moreover, in some exemplary embodiments, system **100** may further comprise: network **105** (e.g. Internet); and server **106** for storing user data in database **107** concerning the sensing data of a user of wearable device **101**, which may be transmitted to client device **103** and communicated to server **106** via network **105**. In some exemplary embodiments, server **106** may host a user interface **108** such as a web interface or website accessible to client devices, including for example client device **104**, which may not necessarily receive data directly from wearable device **101**, but may be used to access user's data provided by wearable device **101** from a remote location via access of website **108**. Each of these components of system **100** will be discussed in turn.

[0064] Wearable device **101** may be have different structures and configurations including one or more sensors for gathering sensing data of a user. For example, and without limiting the scope of the present invention, wearable device **101** may comprise a wearable band, bandage, tape patch, or any other wearable structure including a garment that allows a user to attach, adhere or otherwise keep in close contact between the sensors of wearable device **101** and the user's skin. Generally, wearable device **101** includes circuitry configured to receive sensing data such as continuous temperature readings of the user or wearer of wearable device **101**. A more detailed discussion of wearable device **101** follows below with reference to FIG. **1**(*b*). Wearable device **101** may be configured for single continuous use (i.e. a 24-hour period) or for prolonged continuous use (several months) without deviating from the scope of the present invention, depending on the battery capacity and certain configurations. In exemplary embodiments, wearable device **101** is configured to be worn for prolonged periods of time and may be rechargeable.

[0065] Wearable device **101** is generally configured to continuously receive sensing data, for example body core temperature data, which may be stored locally. In exemplary embodiments, as will be discussed below, other data pertaining to an aspect of a user's health may be received via different sensors that may be included within wearable device **101** or in communication with wearable device **101**, without limiting the scope of the present invention. In some exemplary embodiments, the continuously stored data may be shared by wearable device **101** with one or more client devices such as client device **103** via a short-ranged communication means such as local network **105***a;* in such embodiments, wearable device **101** may implement a communications processor configured for any type of local wireless network communications and may use any number of known technologies such as Wi-Fi™, Bluetooth™, ZigBee™, near field communication (NFC), or any other known protocol to establish a wireless personal area network (WPAN) or any suitable local network with a device such as client device **103**. In other exemplary embodiments, the continuously stored data may be shared by wearable device **101** directly with a server, such as server **106**, in order to store and back-up the data remotely and or to make the data available to the user or authorized users from a remote location via a device such as client device **104**; in such embodiments, wearable device **101** may be configured to communicate via a communication means such as wide area network **105** using different technologies, for example cellular or using a locally available Wi-Fi™ network. In a preferred embodiment, wearable device **101** communicates with other devices only via a short-ranged communication means for security (and battery-conserving) reasons, and does not access a wide area network such as the Internet; any data that may be desirably stored in server **106** may be transmitted exclusively through an authorized device such as client device **103**.

[0066] Programmable instructions **102** typically reside in a memory of wearable device **101**. In exemplary embodiments, programmable instructions **102** may be configured to: generate sensing data (for example, and without limiting the scope of the present invention, generate temperature data); determine a state of wearable device **101**; transmit sensing data to client device **103** or server **106**; implement one or more algorithms for power management such as throttling communications, or other battery life preserving techniques; implement security protocols such as encryption protocols for transmitting user data securely or access protocols for allowing devices such as client device **103** to share a security key with other trusted client devices of the user; and any other instructions that may be suitable for proper functioning and or management of wearable device **101**. A more detailed discussion of various algorithms that may be implemented via programmable instructions of a wearable device in accordance with the present invention, are presented below with reference to other figures.

[0067] Client device **103** may be any type of computing device such as a mobile device—including a smartphone or tablet—a laptop computer, a desktop computer, or even a proprietary device dedicated for communicating exclusively with wearable device **101**. In exemplary embodiments however, client device is a smartphone suitable to communicate wirelessly with wearable device **101** via one or more communication channels as well as with server **106** via cellular or wi-fi communication means. For example, and without limiting the scope of the present invention, client device **103** may utilize short ranged communication protocols such as Bluetooth® in order to receive sensing data from wearable device **101**, and access server **106** via a cellular network or wireless LAN to access the internet and transmit the user data to a depository situated at server **106** such as database **107**. Typically, such smartphone will include a dedicated application, such as application **103***a* that facilitates visual and or auditable access to the sensing data and any other type of data including insights that may be provided to the user of wearable device **101** or otherwise an authorized user with permission to receive the user's data.

[0068] Application **103***a* may be any type of software application configured to receive data provided by wearable device **101** and provide the data to a user of client device **103**, as mentioned above. In exemplary embodiments, application **103***a* may be a mobile application that may be downloaded on to a smartphone (client device **103**) in a conventional manner. Typically, application **103***a* reads data from wearable device **101** and displays user parameters derived from this data to the user of client device **103**—for example the wearer of wearable device **101** or an authorized user of the app. Providing the data may mean displaying the data via a display of client device **103** or providing an audio output via one or more speakers of client device **103**. In exemplary embodiments, application **103***a* may synchronize user data with server **106**, such as a server that may be located on the cloud. Generally, application **103***a* displays real-time information concerning the user data obtained from wearable device **101**, although as will be discussed below several algorithms may be implemented to provide the user with useful determinations, insights or conclusions pertaining to a health state of the user based on the user data. Although in some embodiments, as will be discussed below, some of these tasks or determinations may be calculated by a processing unit of the wearable device, typically calculations and determinations based on the user data may be performed by external devices such as client device **103** via application **103***a*. For example, and without limiting the scope of the present invention, wearable device **101** may provide continuous temperature readings through a period of time of a user off the device, and application **103***a* may manage data concerning the temperature readings in order to store the data internally on client device **103** (or remotely on server **106**) and may display the data in a useful manner such as by generating a graph of the stored data when sought by the user.

[0069] Application **103***a* may implement a myriad of features and functionality. In exemplary embodiments, application **103***a* may facilitate synchronization, notifications, data management, permissions, etc. For example, and without limiting the scope of the present invention, application **103***a* may provide up to date record keeping of data by seeking information it has not previously received from the wearable device; application **103***a* may also enable a user to select by what means the user wants to be notified; application **103***a* may enable a user to enter reminders that notify the user when the timing is appropriate for a specific action—such as reminders for a user to put on the device at a particular time in the day so that she does so before going to bed—examples of notifications may be text notifications or reminders. As an extension, it may allow the user to be notified on a separate device connected to the phone such as a smartwatch or an Amazon Echo. Other types of notification measures may be provided such as setting up alarms that detect whether wearable device **101** has been shut down, or whether application **103***a* may have been disabled; this may occur if the operating system resets or the application terminates. Naturally, a person of ordinary skill in the art will appreciate that other various means of notifications and reminders useful to users may be implemented without deviating from the scope of the present invention.

[0070] Network **105** is typically a wide area network, as mentioned above, for example the World Wide Web or Internet. Network **105** may be a means to remotely access server **106** in order for a user to access or otherwise manage their user data or provide access to another authorized user such as a physician or caregiver that may want to access the user's health data from a remote location. As such, network **105** is typically used for remote access, data management, or data backup as desired. As mentioned above, in some exemplary embodiments, no remote server **106** is required and remote data access is not part of system **100**. In such embodiments, a user may simply access and manage their user data via client device **103**, which typically communicates with wearable device **101** via a short-range communication network such as network **105***a*.

[0071] Network **105***a* may be any type of local wireless network and may use any number of known technologies such as Wi-Fi™, Bluetooth™, ZigBee™, near field communication (NFC), or any other known protocol to establish a wireless personal area network (WPAN) or any suitable local network which may be joined by a mobile device such as a smartphone, a tablet, lap top computer or any other mobile device such as client device **103** that has been configured and authorized to communicate with wearable device **101**.

[0072] Server **106** may be configured with any known techniques and in any known manner to achieve a desired security and functionality. In exemplary embodiments, server **106** is a World Wide Web (WWW) server connected to the internet accessible via network **105**. For example, and without limiting the scope of the present invention, server **106** typically includes one or more computers suitable for connecting to network **105**. Optionally, server **106** may provide authorized entities, for example a user's physician, access to user data by means of a standardized interface, such as an application programming interface (API), web service, a website, or any other user interface **108**, which may facilitate management or access to user data via client device **104** of system **100**. In an exemplary embodiment, server **106** may comprise a two-tier server setup with one database layer and one application (web server) layer. This may allow the system to scale user wise by load balancing the application layer and also provide increased security. Without deviating from the scope of the present invention, a cloud based system may run on servers in the Amazon Virtual Private Cloud environment. Database backups may be encrypted and stored in Amazon's Simple Storage Service (S3). All security and firewalls may be configured using best practices and industry standard methods. Access to servers may be limited and monitored. All system access attempts (success or failure) may be logged in the database and physical log files as well as access to any base entities.

[0073] Database **107** may be similarly implement with known database architectures to store user data provided via wearable device **101** as well as any insights, determinations, calculations or other data that may be derived via application **103***a* of client device **103** such as charts, tables, notifications, settings and other useful information pertaining to a user of wearable device **101**. Database **107** may hold multiple databases containing data objects within data repositories collected by server **106**. The databases may be created by a known database manager using known technologies. In one embodiment, server **106** relies on cloud computing and database **107** may include technologies similar to those offered by Amazon™ such as Amazon™ Elastic Compute Cloud (AWS EC2), whereby database **107** may employ MySQL™ and AWS EC2™ instances.

[0074] As mentioned above, system **100** may optionally implement user interface **108**, which may be a website, a web service or any type of application programming interface that provides users with access to the data collected by wearable device **101** and any insights generated through application **103***a* and provided to server **106** via client device **103** or that may be optionally generated by user interface **108** and stored in database **107**.

[0075] Overall, system **100** centers around the electromechanical design of wearable device **101** to facilitate antenna function and transmission of heat from the user's body to one or more sensors of wearable device **101**. As will be discussed in turn, wearable device **101** comprises of several components. FIG. **1**(*b*) illustrates a diagram of several of these components as well as a flow chart of a method of providing temperature sensing data in accordance with practice of an exemplary embodiment.

[0076] Referring to FIG. **1**(*b*), wearable device **101** may comprises of: temperature sensitive device or temperature to voltage converter **111**, which measures temperature of a user; analog to digital converter **112**, which converts the measurement to a digital signal; microprocessor **113** for processing the digital signal into a data payload; memory module **114**, which in exemplary embodiments typically (although not necessarily) comprises non-volatile RAM memory for storing sensing data and or executable instructions such as programmable instructions **102**; and communications processor **115** for transmitting temperature data through antenna impedance matching circuit **116** and antenna **117**. Wearable device **101** may be powered by battery **120**, through an optional electronic load switch **121**, which gates the battery power from the battery (under a microprocessor or user controlled switch). In exemplary embodiments, wearable device may include an input device **118** that may provide a variety of functions, including for example a means to reset or turn off wearable device **101**. In one embodiment, a single switch (or button **126**) controls system power as well as input to the Microprocessor (as opposed to two separate switches). In some exemplary embodiments, wearable device **101** may further include additional user interface elements such as light emitting devices or LEDs **119** to provide indications to the user.

[0077] A temperature sensitive device such as temperature to voltage converter **111** may include one or more temperature sensors of an adequate size and sensitivity suitable for implementation into a circuitry of wearable device **111**. Whatever configuration of the one or more sensors, temperature to voltage converter **111** is preferably situated on a layer of a flexible printed circuit board (PCB **123**) with access to a circuit contact region that contacts the user's skin; as will be discussed in more detail below with reference to other figures, in exemplary embodiments, temperature to voltage converter **111** is preferably configurable to connect with the users skin via several printed pathways such as vertical interconnect access or vias between the layers of PCB **123**. In one embodiment, two temperature sensors may be separated out such that one is in close thermal contact with the skin (sensor 1) and the other (sensor 2) is in better thermal contact with the ambient. The difference in temperature between sensor 1 and sensor 2 may be used to calculate the gradient of heat dissipation, which may be used to derive an accurate measure of skin temperature when the housing of the device is not thermally insulating. The combination of sensor 1 and sensor 2 may also be used for detecting faulty application of the device or when the device has fallen off the body.

[0078] Analog to digital converter **112** may be any device suitable for converting sensing signals to digital signals that may be read by microprocessor **113**. Although shown as a separate component, a temperature sensing device that includes such converting means does not deviate from the scope of the present invention.

[0079] Microprocessor **113** may include one or more processing units suitable for executing programmable instructions **102**. Accordingly, microprocessor **113** may be configured to: receiving temperature data from temperature sensitive device **111** on flexible PCB **123** that is folded to form multiple layers, wherein temperature sensitive device **111** is situated on a first layer of PCB **123**, including a circuit with a contact region etched on a second layer of the PCB **123**, the circuit including one or more pathways or vias connecting the contact region of the circuit to the temperature sensor; generating one or more data packets associated with the temperature data; and sending via an antenna situated on a second layer of the flexible circuit, the one or more data packets associated with the temperature data to a client device, such as client device **103**.

[0080] As mentioned above, in exemplary embodiments, typically memory **114** comprises non-volatile memory or NVRAM suitable for storing the temperature data received from temperature sensing device **112** as well as suitable for storing programmable instructions **102**. However, a person of ordinary skill in the art will appreciate that other memory configurations may be possible without deviating from the scope of the present invention (including combining the NVRAM with Processor)

[0081] Communication processor **115** and antenna impedance matching circuit **116** may be separate components or part of a single communications module without limitation. In an exemplary embodiment, a wireless interface may be provided and configured to implement Bluetooth or Bluetooth Low Energy or wireless LAN or Near-Field Communications (NFC for short) or cellular or LoRAN or a combination of two or more communications systems.

[0082] Antenna **117** may be any suitable antenna for transmitting user data captured by temperature sensing device **114** or any other sensing unit available to wearable device **101**. In exemplary embodiments, antenna **117** is strategically placed on one of the layers of flexible PCB **123**, which is preferably folded so as to allow placement of antenna **117** on a first plane of a layer of PCB **123**, and placement of the ground (to antenna **117**) on a different (opposite) plane of the PCB **123**. A more detailed discussion of such exemplary antenna configuration is discussed with reference to FIG. **4**(*b*).

[0083] Input device **118**, as mentioned above, may be any type of input such as a simple button. This may be implement as a simple actuator device or in more complex embodiments input device **118** may include a touch interface part of a display (optionally shown as **118***a*) of wearable device **101**.

[0084] LEDs **119** may provide a visual indicator to a user, especially in embodiments of wearable device **101** that do not include a display. Multiple color LEDs may provide useful feedback including but not limited to: a power (or battery usage) status of wearable device **101**; a communication status (i.e. whether transmitting, not transmitting, accessible, airplane mode, etc.) of wearable device **101**; a temperature status or threshold; or any other useful status that may be conveyed visually through simple LEDs to a user of wearable device **101**; these indication can be distinguished by using multiple colors and blinking. In exemplary embodiments, LEDs **119** may be a means to alert the user by blinking—for example and without limiting the present invention—red, on a surface enclosure or housing of wearable device **101**. This may be particularly useful if wearable device **101** has detected that there are no smartphones or tablets in communication range, and a need for alerting a status to the user is desirable. In some exemplary embodiments, as a careful tradeoff between power consumption and alerting, LEDs **119** may be kept blinking for a short duration before wearable device **101** is shut down. In some exemplary embodiments, when the wearable device detects that sensing or communications functions in the wearable device are not working or that, for example, client device **103** is not in range of wearable device **101**, then LEDs **119** may indicate that a malfunction has occurred. Malfunction may also indicate that the battery is low, meaning the device should be recharged or discarded if the battery is not rechargeable. The indication may be executed for a short, fixed duration to ensure that the battery does not drain fully.

[0085] Moreover, in some exemplary embodiments, LEDs may be useful in providing self-test information indicative of a malfunction. Detecting a malfunction in the wearable device is necessary for safe and reliable use of the device. In the present invention, this may be achieved by means of a self-test that checks sensing, communications, and security functions in the wearable device. The process may begin during production of the device. During production, a test maybe implemented to run and store the identification information of major components in of wearable device **101**. This may include the Electronic Serial Number of the sensor or the device ID in the processor. In active use of wearable device **101**, a self-test may be run every time the processor is powered up and then, the test may be run periodically. This test checks to see if the processor is connected to components and if the components identify themselves as the ones in information that was stored during production. A break in the connection to the components or a mismatch in any of the parameters read, indicates that the device has lost hardware integrity and thus has malfunctioned. In some embodiments, an indication of malfunction may be broadcasted to a client device such as client device **103**. If it is so detected that the device is unable to broadcast its condition, then the device may use LEDs **119** to indicate that the device is malfunctioning. In exemplary embodiments, after communicating the state of malfunction, the device may erase all user data on memory **114** and shut itself down. Moreover, in exemplary embodiments, the pattern emitted by the LEDs may be used to identify the specific malfunction. For example, a series of ON signals may identify that the malfunction code is equal to the number of times the LEDs turned on.

[0086] Moreover, although wearable device **101** is disclosed as including LEDs **119**, in other exemplary embodiments, these may be replaced or used in conjunction with actuators that provide tactile and or auditory feedback to the user that is wearing the device. In exemplary embodiments, a haptic feedback module may be used whereby a vibrating component such as a vibration motor or a linear resonant actuator is driven by microprocessor **113** or by a dedicated hap tic driver chip (not shown).

[0087] Battery **120** may be a primary cell or a rechargeable battery or an energy harvesting circuit, without limiting the scope of the present invention. Furthermore, load switch **121** may be any type of load switch, relay or may be replaced by a power management integrated circuit. In an exemplary embodiment of wearable device **101**, battery **120** is rechargeable; a wireless charging coil may be added to the circuitry of wearable device **101** so that battery **120** may be charged by an external charging mechanism without the use of exposed electrical contacts. In other exemplary embodiments, a separate charger may consist of a charging coil, a charging circuit and a USB voltage adapter that may be used to charge rechargeable battery **120** in wearable device **101**.

[0088] Accelerometer **122** may be implemented in some exemplary embodiments of wearable device **101**. In such embodiments, accelerometer **122** may be connected to microprocessor **113** as a means to measure the motion of the subject body to which wearable device **101** is connected. In such embodiments, wearable device **101** may provide motion data along with the temperature data, which may be useful for detection of an individual's health using their respiration rate and their body temperature.

[0089] Although not shown in this figure, other sensors and sensing devices may be incorporated with wearable device **101** without deviating from the scope of the present invention. For example, in addition temperature sensing device **112** and accelerometer **122** other sensing devices such as a heart rate sensor and device that records the user's pulmonary ventilation may be worn on the user's body and configured for communication with wearable device **101**. In such embodiments body temperature detection may be combined with respiration rate and heart rate to detect a sudden motion of the user such as a fall and subsequent health condition.

[0090] As briefly mentioned above, PCB **123** is a flexible printed circuit board that is folded so as to create multiple layers. In exemplary embodiments, PCB **123** is folded with one of the folds creating a layer for housing antenna **117** and layer for housing the ground for antenna **117**. This electrical layout of antenna **117** and its ground plane create a well-grounded radiating structure that can withstand the proximity to human tissue; this is very useful for a device that may be placed at the axillary region of the human body where temperature readings are medically accepted as accurate, and where incidentally the cavity and tissue of that region tends to attenuate radio frequency signals. In such embodiment, the configuration of the grounded layer or ground plane makes the resonant structure of antenna **117** less susceptible to detuning caused by the proximity of skin.

[0091] Similarly, one of the layers of PCB **123** may house temperature sensing device **112**. Typically, this is a layer that is parallel to a layer that makes contact with or is closest to the skin of the user. In exemplary embodiments, the sensor may include a circuit or structure, such as a copper structure, which may utilize multiple copper vias in PCB **123** to conduct heat from the body (captured at the contact end situated on the layer closest to the skin) to the sensor situated on the parallel layer. In exemplary embodiments copper may be utilized because copper is highly conductive and the conductivity of copper is more than 100 to 200 times the conductivity of any plastic; essentially the copper area acts as a large receiving pad for the thermal heat flux from the skin. Of course, other materials may be used without deviating from the scope of the present invention.

[0092] PCB **123** may be situated on or incorporate a supportive layer such as a foam substrate housed within an enclosure **124**. The supportive layer may help provide structural support as well as a means to make wearable device **101** more easily adjustable for placement against the body of a user. For example, and without limiting the scope of the present invention, wearable device **101** may incorporate a foam layer for supporting PCB **123** as well as a cloth enclosure that protects PCB **123** and makes wearing these components more comfortable to the user. Naturally, such enclosure **124** may include a means to be worn by the user, including but not limited to an adhesive that is suitable for application to the skin or any other structure such as bands, straps, etc. that may be useful in facilitating the device being worn. In exemplary embodiments, an adhesive is implemented on an enclosure **124** so that wearable device **101** may be placed and affixed at or near the axillary region of a user.

[0093] Turning now to the next set of figures, FIG. **2**(*a*) depicts a bottom view of a flexible PCB for a wearable device in accordance with an exemplary embodiment of the present invention; FIG. **2**(*b*) depicts a top view of the flexible PCB; FIG. **2**(*c*) depicts the flexible PCB partially coupled to a foam layer in accordance with an exemplary embodiment of the present invention; FIG. **2**(*d*) depicts a top view of the flexible PCB partially folded over the foam layer depicted in FIG. **2**(*a*); and FIG. **2**(*e*) depicts a bottom view of the flexible PCB partially folded over and threaded through a portion of the foam layer depicted in FIG. **2**(*a*).

[0094] More specifically, these figures show PCB **200** comprising a first layer that expands across a plane having a first surface **201** (on a first side of the plane) and a second surface **202** (on the opposite side of the plane). Moreover, PCB **200** has been folded at fold **203** to form a second layer on a second plane that is substantially parallel to the first plane. The second plane has a first surface **204** (on a first side of the second plane) and a second surface **205** (on a second side of the second plane).

[0095] On surface **201** several components may be situated, including; circuitry **206** which may comprise of a microprocessor, memory, temperature sensor and communications module; LED circuitry **207**; and contacts **208***a* and **208***b*. As may be appreciated from these figures, PCB **200** includes an elongated flexible substrate with at least three terminal ends **211**, **212** and **213**. A battery **210** may be coupled to PCB **200** at terminal end **213**. An antenna **214** may be situated on surface **205** (FIG. **2**(*b*)) of PCB **200**.

[0096] PCB **200** may be coupled or even threaded through a plastic layer such as a 3M© 1772 foam layer **215** as shown in FIG. **2**(*c*)-(*e*). In these views, it may be appreciated that terminal end **212** of PCB **200** has been inserted through an opening or slit **216** of foam layer **215**, and unfolded about fold **203** to expose second surface **205** of the second plane formed by fold **203**. Moreover, foam layer **215** includes an aperture **217** for registering with battery **210**. Also from these views of FIG. **2**(*d*) and in the view of FIG. **2**(*e*), a surface A of foam layer **215** is visible. PCB **200** has been coupled or registered with foam layer **215**, the elongated portion of surface **201** including terminal end **212** situated against surface B as shown in FIG. **2**(*e*). PCB **200** is shown completely registered with foam layer **215**, including contact **208***a*, which has also been threaded through the opening slit **216** of foam layer **215**.

[0097] Now turning to the next set figures, another exemplary embodiment of a PCB for a wearable device in accordance with the present invention is discussed. FIG. **3**(*a*) depicts a bottom view of a flexible PCB for a wearable device in accordance with an exemplary embodiment of the present invention; and FIG. **3**(*b*) depicts a top view thereof. More specifically, these figures depict a printed circuit board (PCB **300**) comprising a flexible substrate **301** that is folded to form multiple layers providing several surfaces **321**, **322**, **323**, **324**, **325**, and **326**); a temperature sensor **302** situated on a first surface **321** of a first layer of the PCB **300**; a circuit including a thermal contact region **303** etched on a second surface **322** of the first layer of the PCB **300**, the circuit further including one or more heat pathways (see for example FIG. **4**(*c*)) connecting the thermal contact region **303** of the circuit to the temperature sensor **302**; a communication module **304***a* including an antenna situated on one of the multiple layers (and in the shown embodiment on surface **323**) of the PCB **300**; and a microprocessor **304** (in the shown embodiment situated on surface **323**) in communication with the temperature sensor **302** and the communication transmitter **304***a,* the microprocessor **304** configured to continuously obtain temperature sensing data from the temperature sensor **302** and transmit the sensing data to one or more client devices.

[0098] In exemplary embodiments, PCB **300** includes a fold **305** adapted to receive a battery for powering the PCB, the fold **305** connecting a circuitry of the PCB to a cathode **306** of the battery **307** and to an anode **308** of the battery **307**. In exemplary embodiments, PCB **300** may further include a conducting adhesive to adhere a copper surface to terminals of battery **307**, and a connection means from power rails to thermal contact region **303**. In such embodiments, as shown in the current figures, fold **305** creates two opposite surfaces **325** and **326** that sandwich the battery **307** therein. Typically, a button **309** may be coupled along a surface **326** of the PCB **300** in order to, for example and without limiting the scope of the present invention, allow a user to turn on the device, activate or deactivate features of device, and or change operational modes.

[0099] In exemplary embodiments, an antenna ground may be situated on a layer different than the layer on which the antenna is situated such that the antenna and the antenna ground together act as a radiating structure for facilitating communication with the one or more client devices. In other exemplary embodiments, the antenna ground and antenna are situated on the same layer.

[0100] In some exemplary embodiments, the one or more heat pathways connecting the thermal contact region **303** of the circuit to the temperature sensor **302** comprise of a vertical interconnect structure (VIA) between the first layer and the second layer of the PCB **300**, the VIA configured to conduct heat from the thermal contact region **303** to the temperature sensor **302**. In exemplary embodiments, both the VIA and the thermal contact region **303** comprise of copper, such that a set of copper pathways (not shown here but see FIG. **4**(*c*)) connect between sensor **302** on surface **321** with a copper layer etched on surface **322** that makes up the thermal region **303** on surface **322** of PCB **300**.

[0101] In some exemplary embodiments, a thermally insulating adhesive may be applied on top of the temperature sensor **302** and the copper layer of the thermal region **303** to form a heat guide, the heat guide for drawing heat energy from a body of a user to the temperature sensor and minimizing a heat loss.

[0102] As will be better appreciated from other figures below, depending on the type of housing or enclosure employed by a wearable device in accordance with the present invention, PCB **300** may be disposed within a housing within a plurality of layers such as foam or plastic layers that are configured to secure and protect PCB **300** therein, but also to maximize a heat transfer between a user's skin and the temperature sensor **302**.

[0103] For example, and without limiting the scope of the present invention, a first type of exemplary housing is discussed in turn with reference to FIG. **3**(*c*)-FIG. **3**(*h*). FIG.

3(*c*) depicts an exploded view of the flexible PCB **300**, including a housing **300***a* in accordance with an exemplary embodiment of the present invention; FIG. **3**(*d*) depicts a top view of the flexible PCB **300** placed inside a first portion of the housing **300***a;* FIG. **3**(*e*) depicts a bottom view of the flexible PCB **300** inside a second portion of the housing **300***a;* and FIG. **3**(*f*)-**3**(*h*) depict the wearable device fully enclosed in the housing **300***a*.

[0104] Turning first to FIG. **3**(*c*), the exploded view shows housing **300***a* including a bottom enclosure **310** and a second portion such as a top enclosure **311**, each portion configured to receive a portion of PCB **300** therein. In exemplary embodiments, enclosure **310** may include an aperture **312** suitable for receiving a portion of PCB **300**, such as battery **307** coupled to PCB **300**. Enclosures **310** and **311** may comprise any material suitable for securing PCB **300** therein, including but not limited to a foam material or a plastic material. For example, and without limiting the scope of the present invention, enclosures **310** and **311** may comprise a liquid silicone rubber, such as Dow Corning© QP1-250, having a silicone sealant disposed along an interior surface of each enclosure (i.e. for example around the edges). In exemplary embodiments, enclosure **311** includes an aperture **313**, which further includes a smaller aperture **314** within aperture **313** for receiving a portion of button **309** of PCB **300** therein. In exemplary embodiments, a portion **331** of enclosure **310** may have a reduced thickness from a thickness of the entire enclosure **310** so that when PCB **300** lays on top or along a surface of portion **331** of enclosure **310**, heat may be more easily transferred between the user's skin and the thermal region **303** that lays along said surface of portion **331** of enclosure **310**. A portion **332** of enclosure **311** may have a similar gradual change in thickness or may be equal in thickness along an entire length of enclosure **311**. In exemplary embodiments, an added thickness protects the thermal sensor **302** that lays along a surface of portion **332** of enclosure **311** so that the antenna of the device is on the same plane as sensor **302**.

[0105] With reference to FIG. **3**(*d*), in this exemplary embodiment of the wearable device, PCB **300** may typically lay within the bottom enclosure **310** such that a bottom portion of battery **307** (i.e. including cathode **306**) is received within aperture **312**, and a first surface **321** on a first layer of PCB **300** is exposed—thereby exposing thermal sensor **302**. As such, a second surface **322** on the opposite side of the first layer of the PCB **300** will be situated against a surface of portion **331** of enclosure **310** of housing **300***a*. As may be appreciated from this view, fold **305**—which sandwiches battery **307** within, creates a layer of the PCB **300** situated within aperture **312** with button **309** exposed on another layer of the PCB **300**. Surface **324** of PCB **300** then lays substantially parallel with surface **321**.

[0106] With reference to FIG. **3**(*e*), in this exemplary embodiment of the wearable device, PCB **300** may typically lay within the top enclosure **311** such that a top portion of battery **307** (i.e. including anode **308**) is received within aperture **313**—and more specifically so that a portion of button **309** is situated within aperture **314** (within aperture **313**) of enclosure **311**. In this way, surface **322** on the first layer of PCB **300** is exposed—thereby exposing thermal region **303** (i.e. whenever enclosure **310** is decoupled from enclosure **311**). As such, the first surface **321** on the opposite side of the first layer of the PCB **300** will be situated against a surface of portion **322** of enclosure **311** of housing **300***a*. As may be appreciated from this view, fold **305**—which sandwiches battery **307** within, creates a layer of the PCB **300** situated within aperture **313** with button **309** also therein. Surface **323** of PCB **300** then lays substantially parallel with surface **322**.

[0107] Now with reference to FIG. **3**(*f*), FIG. **3**(*g*), and FIG. **3**(*h*), it may be appreciated from these views that when each enclosure **310** and **311** is secured to each other (for example using a silicone sealant to adhere the two enclosures), PCB **300** is sandwiched within housing **300***a*. Accordingly, in this exemplary embodiment, PCB **300** is secured within housing **300***a* so that surfaces **321** and **324** lay substantially parallel along the same plane on a top side of housing **300***a* with a portion of battery **307** and button **309** within cavity **313** and **314**, respectively, and surfaces **322** and **323** lay substantially parallel on an opposite side of the same plane on a bottom side of housing **300***a,* with a portion of battery **307** and cathode **306** of battery **307** within cavity **312**. From this view, it may be appreciated that thermal region **303** of PCB **300** may be disposed along a surface on portion **331** of enclosure **310** that comprises a thinner layer of plastic so as to facilitate the transfer of heat between a user's skin and sensor **302**.

[0108] Now turning to the next set of figures, a second type of exemplary housing is discussed in turn with reference to FIG. **3**(*i*)-FIG. **3**(*k*). FIG. **3**(*i*) depicts an exploded view of flexible PCB **300**, which may be secured within a housing **300***b* in accordance with an exemplary embodiment of the present invention; FIG. **3**(*j*) depicts a top exploded view of the flexible PCB threadedly secured inside a foam or plastic layer **316** of housing **300***b* with a top plastic or foam layer **320**; and FIG. **3**(*k*) depicts a bottom exploded view of the flexible PCB **300** secured to layer **316** with a bottom plastic or foam layer **319**.

[0109] More specifically, in this embodiment, housing **300***b* differs from housing **300***a* in that housing **300***b* includes a middle support layer **316**, onto which PCB **300** is threadedly secured thereto, which is sandwiched between a top layer **320** and a bottom layer **319**. This construction may be flexible so as to conform to a user's body and facilitate a comfortable fit against the user when the wearable device is worn. As such, housing **300***b* may include a top layer **320** and a bottom layer **319**, each which may comprise a foam material that is generally flexible and soft. Middle layer **316** may include a plurality of apertures **318** and **317** adapted to receive portions of PCB **300**, so that PCB **300** may be secured within each aperture.

[0110] In an exemplary embodiment, and without limiting the scope of the present invention, bottom layer **319** and top layer **320** are planar layers with substantially smooth surfaces, each layer **319** and **320** having an elongated oval perimeter with substantially round edges. In some exemplary embodiments, such as shown in these figures, each layer **316**, **319**, and **320** has a terminal end that is slightly narrower than the opposite terminal end. This construction, including the softer materials, the rounded edges and the oblong, elongated perimeter with a narrower terminal end, facilitates a more comfortable wear by a user.

[0111] In the shown exemplary embodiment, middle layer **316** is a support layer that includes an aperture **318** in a middle portion along the length of layer **316**, which is adapted to receive a portion of battery **307** of PCB **300**. At one of the terminal ends, for example and without limitation. the narrower terminal end, a second aperture **317** may be adapted to receive sensor **302** within. This way, sensor **302** may be protected within the aperture **317** and also ensure that a user avoids feeling any non-flexible or less flexible components such as the battery and the sensor of PCB **300**, when the wearable device is pressed against the skin.

[0112] With reference to FIG. **3**(*j*) and FIG. **3**(*k*), it may be appreciated that once threaded through these apertures **318** and **317**, the surfaces of PCB **300** will be positioned slightly different than when housed in a housing such as housing **300***a*. For example and without limiting the scope of the present invention, where a first layer of the PCB **300** may include on a first surface **321** and an opposite surface **322** of the first layer of PCB **300**, a second layer of PCB **300** may include a third surface **323** and an opposite surface **324** of the second layer of PCB **300**, wherein PCB **300** is threaded through aperture **318** of layer **316** such that the first layer is situated on a different plane than the second layer. In the current figures, for example, it may be appreciated that surface **324** (of the second layer) is situated on an opposite side of layer **316** and thus on a different plane than surface **322**.

[0113] Moreover, in exemplary embodiments, because thermal region **303** is placed against bottom layer **319**, which in turn will be in contact with the user's skin in order to detect a temperature, layer **319** may comprise a thin layer so as to facilitate heat conductivity to sensor **303** via the heat pathways connecting thermal region **303** with sensor **302** of PCB **300**.

[0114] Turning now to the next figure, FIG. **4**(*a*) illustrates different layers of a PCB in accordance with an exemplary embodiment of the present invention, such as an embodiment in accordance with FIG. **2**(*a*)-FIG. **2**(*e*). More specifically, FIG. **4**(*a*) depicts a wearable device **400** that comprises a flexible PCB **400***a* folded around and in between multiple layers of polymeric foam or plastic—this embodiment consistent with the embodiment disclosed in FIG. **2**(*a*)-FIG. **2**(*e*). In the shown exemplary embodiment, a flexible PCB **400***a* is folded at fold **412** (see FIG. **4**(*b*)), which provides a connecting layer for an antenna's ground plane **413** between a lower layer **403** of the flexible PCB **400***a*, and an upper layer **405** of the flexible PCB **400***a*. A base layer **401**, typically closest to the skin, may be made of foam or plastic that is constructed to be thermally conducting and electrically insulating. This layer is attached to the lower layer **403** of flexible PCB **400***a* by means of a thermally conducting adhesive layer **402**. The lower layer **403** of flexible PCB **400***a* houses electronics, circuit traces and the connection to the battery **408**. The lower layer **403** of flexible PCB **400***a* may be attached to a middle layer **404** that may be made of foam or plastic that constructed to provide thermal insulation and physical rigidity for wearable device **400**. In the shown exemplary embodiment, the middle layer **404** is then attached to the top layer **405** of flexible PCB **400***a*. Moreover, middle layer **404**, which is connected to the battery **408**, contains or houses the antenna **410** within (for example as seen in FIG. **3**(*a*)-(*d*)). The top layer **405** of flexible PCB **400***a* may be attached, using adhesive layer **409**, to an additional layer **406** that may be similarly constructed of foam or plastic, which similarly provides thermal and electrical insulation as layers **401** and **404**. Layer **406** may be attached to a label **407**, which provides product labeling, using adhesive layer **410**. The battery **408** may be situated between the two layers **403** and **405** of flexible PCB **400***a*, for example—as mentioned above—situated on or within an aperture foam layer **404**. See for example aperture **217** of the embodiment disclosed with reference to FIG. **3**(*a*). The folding of the PCB **400***a* about fold **412** surrounds the foam or plastic layer **404**, which is an electrically non-conducting and thermally insulating layer between the layers of PCB **400***a*. In an exemplary embodiment, electrical connections to the battery may be made using conductive adhesive fabric that may be stuck to the flexible PCB copper pad or copper area and the battery. Alternatively, copper area may be welded to the battery.

[0115] Turning to the next figure, FIG. **4**(*b*) illustrates a side view of folded PCB **400***a* and the different layers formed therein in accordance with an exemplary embodiment of the present invention. More specifically, FIG. **4**(*b*) illustrates a sub-structure, in which antenna **410**, is placed in the top PCB layer **405** formed when the PCB **400***a* is folded along fold **412**, thereby situating a ground plane **413** at the bottom layer **403** of PCB **400***a*. As mentioned above with reference to FIG. **4**(*a*), the two layers (**403**, **405**) of PCB **400***a* are separated by a foam or plastic layer to maintain a consistent separation **404**. The antenna **410** and the ground plane **413** together act as a radiating structure for communication with a device at the frequency of operation. In exemplary embodiments, the separation between the two layers, substantially equals to the thickness of the foam layer **404**. For example, and without limiting the scope of the present invention, in exemplary embodiments, about 1.6 mm may be used in order to create a reliable radiating structure even when the device containing this sub-structure is attached to the body. A typical radiating antenna structure is built on a hard PCB that will typically have an antenna on one side and a ground plane on the other. This naturally gives a 1.6 mm (or a consistent amount of) separation between the antenna and ground because the hard PCB is 1.6 mm thick. Since the application requires the use of a flexible PCB, which is about 25-50 microns thick, it is not possible to create this separation using the flexible PCB as it is. Accordingly, the ground may be positioned between the resonant structure and the body.

[0116] As may be appreciated by a person of ordinary skill in the art, antennas receive energy from an RF transmitter and radiate it out. Antennas are tuned to the desired frequency of operation, but if the tuning of the antenna does not match the frequency of transmission (or reception), the antenna will reflect most of the energy that is fed to it, back to the source. This will result in a very small amount of energy to go out as radiation, and hence a very weak signal at the receiver. For wearable or on-body devices, the challenge with antenna design is the fact that the tuning of the antenna changes due to the proximity of the body; that is, there is a shift in the tuning when the antenna is placed against the body. This is due to the high dielectric constant of the human body which is largely water. (Water has dielectric constant of about 80, where as air has dielectric constant of about 1, most plastics have dielectric constant of 3 to 5). Accordingly, one function for the middle layer of foam is to provide separation between antenna and the ground plane to create a radiating structure that is robust to the distance from the body. The ground plane also acts as a shield to decouple the effect of the body from the resonant structure of the antenna by allowing the electric fields to terminate mainly on the copper ground instead of penetrating the body.

[0117] Turning now to the next figure, FIG. **4**(*c*) illustrates a sensor and heat pathway of an exemplary PCB in accordance with the present invention. More specifically, FIG. **4**(*c*) illustrates flexible PCB **400***a* folded to form multiple layers, wherein a temperature sensor **418** is situated on a first surface of layer **403** of PCB **400***a*, and a circuit, such as a copper circuit, includes a thermal contact region **415** etched on a second surface of layer **403** of PCB **400***a*, the thermal contact region **415** including one or more pathways **416** connecting the contact region **415** of the copper circuit to the temperature sensor **418**, which effectively creates a heat pathway. This configuration helps reduce the time taken to accurately measure the core temperature by guiding body heat to the sensor using the conductive material (for example copper) in the PCB.

[0118] As shown in FIG. **4**(*c*), which is a magnification of only the "heat guide" or pathway, the lower layer of the PCB contains a contact region **415**, which in the shown exemplary embodiment may be made of copper that is connected by one or more pathways such as copper vias **416** that thermally connect opposite surfaces of layer **403** of flexible PCB **400***a;* one surface including copper plate **415**, and another surface including copper layer **417**. Copper layer **417** may be in physical contact with temperature sensor **418**. Optionally, a thermally conducting adhesive **419** may aid in the attachment of copper layer **417** to temperature sensor **418**. Further, optionally, a thermally insulating foam layer, such as layer **404**, may be placed on top of the temperature sensor **418** to minimize heat leakage and hence the effect of ambient temperature.

[0119] In exemplary embodiments, a thermally insulating adhesive may be placed on top of the temperature sensor **418** and copper layer **417**; the combination of thermally conducting bottom foam layer, thermally conducting adhesive, ground plane made of copper and copper vias and optional insulation top of the temperature sensor altogether comprise a heat guide that draws heat energy from the body of the user to temperature sensor **418** and prevents the heat loss to the ambient. With this configuration, temperature sensor **418** rapidly achieves thermal equilibrium with the body, thereby allowing for rapid measurement of the body's temperature. This is because, in order to reach thermal equilibrium, the temperature difference between the sensor, all elements in thermal proximity to the sensor and their heat capacity come into play. The novelty here is in the use of the two copper pads, one in the proximity of the skin and the other connected to the temperature sensing element and large number of copper vias between the two copper pads. The copper pad in the proximity of skin acts as a receiver of the heat flux from the body. The copper pad also conducts heat to the vias that connect the two copper pads. Even though the vias have a small cross-section, there may be many of them, allowing sufficient amount of heat to be transmitted to temperature sensor **418** in order to achieve temperature equilibrium in seconds rather than minutes. As mentioned briefly above, the heat pathway and heat guide discussed with reference to FIG. **4**(*c*) may be employed with a wearable device utilizing a PCB such as PCB **300** rather than PCB **400**, without deviating from or limiting the scope of the present invention.

[0120] In exemplary embodiments of the present invention, a second temperature sensor or even multiple temperature sensors may be utilized. An ideal placement for a second and subsequent temperature sensors may be on **405**—the temperature gradient between the skin and temperature sensitive devices—in order to measure, during transients and in steady state, the temperature of the ambient; the first sensor measures the temperature of the skin. This would allow for a method to measure accurately the skin temperature even in the presence of heat leakage in the device. Another application of the second temperature sensor would be to calibrate the measurements made by the first temperature sensor. A further application of the combination of the two or more sensors is in the use of error or fault detection, error estimation and error correction while the device is being used for its primary function. A typical use of the combination of the two or more sensors is in self-test.

[0121] Finally, FIG. **4**(*d*) illustrates a close-up view of another exemplary embodiment of a flexible PCB and foam configuration in accordance with the present invention. More specifically, FIG. **4**(*d*) shows components of a flexible PCB **421**, which may be folded so that they protrude out through notches into a bottom foam layer **422** and attach to metal contacts **423** over a copper area **424**.

[0122] As mentioned above, a system in accordance with the present invention may include a wearable device that is configured to detect a voltage difference as well as or in the alternative to temperature data. A common example of a system of measuring potential differences within the human body is provided by the electrocardiogram (ECG), which refers to a plot against time of the varying potential differences existing between various standard electrode pairs positioned on the surface of the body. A conventional ECG measurement will include twelve signal measurements, also referred to as "leads", that are taken using a set of standard electrodes pairs. Utilizing this same principle, it is possible that a wearable device in accordance with the present invention is configured to receive signals indicative of a plurality of voltage measurements of the human body, and generate voltage differential signals associated with the differences in said voltages, in order to generate voltage differential data that may be used, for example, by a physician such as a cardiologist to diagnose a particular condition.

[0123] Next, FIG. **5**(*a*) illustrates a flow chart of an exemplary method of reading potential difference data. More specifically, FIG. **5**(*a*) shows method **500** for utilizing a voltage difference measured between two or more electrical contacts in order to generate a digital measurement. It is noted that although method **500** is shown in a particular sequence of steps, other conceivable sequence of the steps may be practiced without deviating from the scope of the present invention.

[0124] Generally, at step **501**, voltage measured at a first contact, such as a first copper contact may be received. Similarly, at step **502**, voltage measured at a second contact, such as a second copper contact may be received. In step **503**, a voltage difference measured between the first contact and the second contact may be amplified by using an amplifier circuit including but not limited to a differential input amplifier **516**, filtered using a filter circuit **516**, and then converted to a digital measurement using an analog-to-digital-converter **517**, at step **504** thereby producing a digital measurement that is derived from the input voltage difference. In another embodiment, the voltages from the metal contacts may be fed directly to the analog-to-digital convertor wherein the amplification and filtering may be done digitally.

[0125] In exemplary embodiments, the amplifier circuit may be combined with the filter circuit such as by using an operational amplifier with a filter in the feedback circuit. Further, in other exemplary embodiments, one or both of the contacts used for measuring the voltage difference may also be used as the heat collector for measuring temperature.

[0126] In some exemplary embodiments, a temperature measurement may be combined with the digital measurement of voltage difference and a combination of the two measurements may be created. In such embodiments, the PCB may be extended to connect to two electrical contacts that are either in direct contact with the skin or in contact to the skin through heat-conducting adhesive.

[0127] An exemplary application of measuring the voltage difference as in method **500** may be in the measurement of the heart rate, which may be computed from the voltage difference as the measure of periodicity of the electrical waveform. The combination of temperature and voltage difference thus leads into applications that use both the body's temperature and the heart rate such as in the measurement of the body's calorific output, the detection of physiological stress, the detection of psychological stress and the detection of shock. As such, a wearable device in accordance with the present invention may implement a method for measuring temperature and heart rate concurrently using a single wearable device.

[0128] Another exemplary application of measuring the voltage difference as in method **500** may be in the measurement of heart rate variability, which is simply a measure of the change in periodicity of the electrical voltage difference when the device is placed in the armpit. Measures of heart rate variability are temperature dependent in the range of therapeutic hypothermia to normothermia. Core body temperature needs to be considered when evaluating heart rate variability metrics as potential physiologic biomarkers of illness severity in hypoxic-ischemic encephalopathy infants undergoing therapeutic hypothermia. As such, the combination of core body temperature and heart rate variability derived from a wearable device in accordance with the present invention device may be useful in the diagnosis of illness severity in hypoxic-ischemic encephalopathy infants undergoing therapeutic hypothermia.

[0129] Accordingly, several applications are possible with the information that may be gathered and generated with use of a wearable device in accordance with the present invention. As the following figure illustrates other types of information may be derived from sensing data such as the data generated by one or more temperature sensors of the wearable device.

[0130] One such example is disclosed with reference to FIG. **5**(*b*), as well as FIG. **5**(*c*) and FIG. **5**(*d*). These figures illustrate exemplary embodiments in which the wearable device includes multiple electrically-conducting contacts, some of which may be placed on the side facing the skin and some others on the other side and exclude temperature sensors so that the wearable device is configured to read and transmit voltage differential data of the wearer.

[0131] With regards to the first of these three figures, FIG. **5**(*b*) illustrates a block diagram of a wearable device **510** including multiple electrically-conducting contacts **511**, **512**, **513**, and **514** and does not necessarily include a temperature sensor. Wearable device **510** is as mentioned above configured to generate voltage differentials pertaining to a user, in accordance with exemplary embodiments of the present invention. Specifically, wearable device **500** includes contacts **511-514**, which may be coupled to a signal selector, such as a multiplexer, or even as shown multiple multiplexers, mux 1 and mux 2, which receive voltage signals from contacts **511-514**, wherein in each mux 1 and mux 2 receive signals from all contacts **511-514**. Each mux 1 and mux 2 configured to select pairs of electrodes whose voltages are input to the differential input amplifier **515** and filter **516**. A microprocessor **518** may be coupled to the plurality of multiplexers (mux 1 and mux 2), the microprocessor including a memory with a set of executable instructions or logic for generating a plurality of measurements comprising the voltage differences from the voltage values received from each of contacts **511-514**. The configuration of the multiplexers in the selection of the contacts may be systematic or may be dynamically driven by the microprocessor, as described later.

[0132] In exemplary embodiments, a feedback module such as haptic feedback module **519** may be coupled to microprocessor **518**, such that microprocessor **518** is further configured to generate a feedback signal whenever an algorithm of the executable instructions detects an abnormality. For example, and without limiting the scope of the present invention, in exemplary embodiments, when a voltage differential yields a certain value that may be indicative of a medical condition (such as an anomaly in said voltage differentials for the wearer), the microprocessor **518** may be configured to send a feedback signal to a feedback module such as haptic feedback module **519** in order to alert the user.

[0133] Exemplarily, haptic feedback module may provide a vibration or other similar feedback that alerts the user to the anomaly. Of course, in other exemplary embodiments, a feedback module may include an audio signal, a visual signal or any combination thereof. Moreover, wearable device **510** may further include a communications module including a transmitter. In such embodiments, microprocessor **518** may be further configured to send a signal to one or more client devices. Moreover, the transmitter may be utilized to send the voltage differential data to the one or more client devices for storage and or further processing.

[0134] In exemplary embodiments, device **510** may be placed against a portion of a user's skin such as right below the heart and to the center of the chest area. In such exemplary embodiments, contacts **511** and **512** (may be in direct contact or substantially in contact with a user's skin so that voltage readings from the user's body may be received via said contacts. As such, device **510** may be continuously receiving voltage information. In the event that an anomaly in voltage differences is detected, the user may be prompted with an alert via haptic feedback module **519** to interact or activate the other contacts of the wearable device **510**, as will be described below with reference to FIG. **5**(*c*) and FIG. **5**(*d*), as well as with reference to the method depicted in FIG. **5**(*e*).

[0135] With reference to FIG. **5**(*c*) and FIG. **5**(*d*), these figures show, respectively, a top and bottom view of another device in accordance with the present invention, wherein a first contact **511** and a second contact **512** may be situated and exposed via a top surface of a housing **510** of the wearable device **500***a*. Further, a third contact **513** and a fourth contact **514** may be situated and exposed via a bottom surface of housing **510** of wearable device **500***a*. All such contacts may embody a structure similar to that described with reference to FIG. **4**(*d*). Such wearable device **500***a* may be worn, for example, on the chest such that contacts **513** and **514** touch the user's skin and such that contact **511** and **512** may be exposed. With this configuration, which facilitates a user to touch each of the top surface contacts **511** and **512**, much more meaning full data (other than simple heart beat information) may be generated by wearable device **500***a* such as echocardiographic data from which meaningful insights and or diagnostic interpretations may be extrapolated.

[0136] FIG. **5**(*e*) is a flow chart depicting an exemplary method employed by an exemplary embodiment of the wearable device illustrated in FIG. **5**(*b*)-FIG. **5**(*c*). More specifically, FIG. **5**(*e*) shows method **520** performed by device **510** for providing voltage differential data. It is noted that although method **520** is shown in a particular sequence of steps, other conceivable sequence of the steps may be practiced without deviating from the scope of the present invention.

[0137] In step **521**, a measurement may be taken from a first contact and a second contact such as contact **511** and contact **512**, wherein the measurement comprises the difference between a first voltage V**1** and a second voltage V**2** (V**1**-V**2**) wherein V**1** and V**2** represent the voltage measured at the first contact and the second contact. In step **512**, an algorithm may be performed whereby anomalies may be detected when this differential voltage value (V**1**-V**2**) is compared to previously recorded differential values for V**1**-V**2**. Such comparisons may include the detection of specific features in (V**1**-V**2**), which are then monitored over time. In the event that there is no anomaly, or the voltage differential is within a normal range, then the voltage differential data may be stored and or transmitted to one or more client devices at step **528**.

[0138] However, if an anomaly is detected, the microprocessor may generate a signal to activate feedback module so that a signal, such as an audio signal, a visual signal, or a haptic signal may be generated. In exemplary embodiments, a haptic signal is generated via haptic feedback module **519**. In other exemplary embodiments, an LED is lit up. In other exemplary embodiments, an audio is played via a client device or via the wearable device itself, wherein that embodiment includes a small speaker. In other exemplary embodiments, a notification may be provided to a client device to notify a user of the client device or even the wearer. Whether the anomaly activates a haptic feedback module or any other type of signaling means, the user should be prompted to take action and instructed to activate the other contacts of wearable device **510**.

[0139] In step **524**, accordingly, the user places their fingers over the easily accessible contacts **513** and **514** of device **510**. This typically closes a circuit so that additional voltage values of the user's body are received and read by wearable device **510**; V3 is the voltage measured at contact **513** and V4 is the voltage measured at contact **514**. Reading of voltages from third and fourth contacts may be done by selections in the multiplexers, which many be done on command from the microprocessor.

[0140] In step **525**, a determination may be made as to whether the user's fingers are properly detected. If not, the user may be continuously reminded via haptic feedback or otherwise, that an anomaly was detected and or that further action is required. In exemplary embodiments, a reminder with specific instructions may be provided to the user via client device such as a smartphone. If the user's fingers are detected by the wearable device, then a next set of measurements may be taken. Such detection may be done by checking if the voltage amplitude measured at the contact exceeds a certain threshold or by detecting specific features in the measured voltage.

[0141] In step **526**, a series of measurements may be taken from a third contact and a fourth contact such as contact **513** and contact **514**, wherein the series of measurements may comprise V**1**-V**3**, V**2**-V**4**, V**3**-V**4**, and V**1**-V**2**. When the contacts are used for measuring ECG, the voltage differences may be used to derive voltages from bipolar limb leads, measuring of which facilitates the detection of ailments concerning the heart.

[0142] In step **527**, a determination may be made as to whether sufficient data has been collected. If enough data is not collected, the user may be prompted to continue or replace their fingers on the contacts **513** and **514** as mentioned above. If enough data has been received, however, then the data may be transmitted to one or more client devices in step **528**.

[0143] Turning now to the next figure, FIG. **6** illustrates a flow chart of an exemplary method of deriving basal body temperature in exemplary practice of an embodiment of the present invention. More specifically, FIG. **6** shows method **600** for deriving basal body temperature by a client device, with data provided by a wearable device in accordance with the present invention. It is noted that although method **600** is shown in a particular sequence of steps, other conceivable sequence of the steps may be practiced without deviating from the scope of the present invention.

[0144] The basal body temperature of a user is the core body temperature when the user is resting. As such, an application in accordance with the present invention (that is for example executable by a client device such as client device **103**) may utilize temperature data from a wearable device (for example wearable device **101** that is attached to a user) to compute the basal body temperature for the user for a period of 24 hours.

[0145] As illustrated by method **600**, data from the wearable device may be first used to compute the instantaneous temperature of the wearer. Starting at step **601**, data may be received from the wearable device (including a time stamp).

[0146] At step **602**, a first check may be run on this data to determine if the device is still worn on a body by rejecting all results that exceed the normal range of human temperature. The result is the combination (body temperature, state of the device) where the state of the device is either on-body or off-body. All temperature data in off-body state may be ignored.

[0147] At step **603**, for all transitions from on-body to off-body and vice-versa, a buffer zone may be created so that temperature data in this buffer zone may be ignore for calculations of basal body temperature.

[0148] Then, at step **604**, all data that is not ignored may be run through a short-term averaging filter to compensate for noisy measurements, duly tracking the breaks in the data stream. The lowest measured temperature in the averages provide the basal body temperature.

[0149] At step **605**, the timestamp associated with basal body temperature may then be used to refine the 24-hour period for future measurements. One way to adjust the 24-hour period may be to move the time associated with the basal body temperature to the middle of the 24-hour period.

Optionally, the window may be moved by a few minutes per day instead of moving the window abruptly.

[0150] The next set of figures disclose and or illustrate how data from the wearable device may be utilized for deriving useful insights pertaining to the health of the user. Primarily, the next figure illustrates how a wearable device state may be determined, which as shown in the discussion with method **600** is useful information for calculating measurements such as basal body temperature.

[0151] Turning now to the next set of figures, FIG. **7**(*a*) is a chart showing temperature as a function of time, which demonstrates a method for determining different device states in exemplary practice of an embodiment of the present invention. More specifically, FIG. **7**(*a*) depicts chart **700***a* showing a curve representing temperature (T) as a function of time (t) throughout arbitrary periods of time (p_x). Again, this is merely illustrative should not limit the scope of the present invention. More importantly, this information may be used, for example, by an application—such as application **103***a*—to make certain determinations utilizing a state of the wearable device.

[0152] For example, and in no way limiting the scope of the present invention, as may be appreciated from chart **700***a*, between periods t_0 and t_1 the temperature curve is converging, showing the temperature of the wearer increasing. As such, every time temperature data reveals a continuously rise in temperature, a first type of device state **701** may be assigned. This state may be indicative of the device recently being attached to the skin of a user or initially worn; alternatively, this may indicate a rise in the temperature of the wearer. Naturally, a converging state or state **701** may have different implications depending on the condition of the user, such as an abnormal increase in temperature indicative of a serious or worsening condition, an expected increase in temperature as a result of applied heat, or as stated above, merely that the device has been recently worn after nonuse. Accordingly, a first type of device state **701** may be a converging state.

[0153] Similarly, as may be appreciated from chart **700***a*, between periods t_1 and t_2 the temperature curve is steady, showing the temperature of the wearer constant. As such, every time temperature data reveals a constant temperature, a second type of device state **702** may be assigned. This state may be indicative of normal or steady (indicating that the device is being worn, although not necessarily indicating a normal temperature of the user—if for example the user is a patient with a condition where a low or high temperature is expected during a period of time).

[0154] Similarly, as may be appreciated from chart **700***a*, between periods t_2 and t_3 the temperature curve drastically falls, showing the temperature detected by the device decrease severely. As such, every time temperature data reveals a serious decrease in temperature, a third type of device state **703** may be assigned. Although this state may be indicative of a severe condition, it is most likely indicative of the device either falling off, or simply not being worn properly. This information may be useful, for example, to: generate instructions concerning an alert that the device is not properly attached to the wearer, generate instructions concerning notifications that the device will power down, generate instructions concerning power consumption; or useful in certain determinations wherein certain temperature ranges must be ignored as discussed above in reference to method **600**.

[0155] Finally, as may be appreciated from chart **700***a*, between periods t_3 and t_4 the temperature curve is steadily at a nil temperature reading. As such, every time temperature data reveals this state, a fourth type of device state **704** may be assigned to indicate the device has been removed or turned off.

[0156] Each device state may be used by the wearable device's programmable instructions as well as an application on a client device in communication or with access to the data from the wearable device. For example, and without limiting the scope of the present invention, when firmware in the device discovers that it is presently in state **704** wherein the body that it is connected to is well below the human body temperature, the device may conclude that the device has fallen of the body that it was measuring. In that situation, the device may inform the temperature and the state of the device to the application and after a certain time has elapsed, it goes into shutoff mode.

[0157] Moreover, device states may be optionally controlled by a user. For example, and without deviating from the present invention, a user may manually put the wearable device in either state **703** or state **704**. A user may initiate a state **703**, for example, by enabling a type of 'airplane mode' by making a selection in a client device's application in communication with the wearable device; in airplane mode, the processor/RF transmitter power may be disconnected preventing inadvertent data transmission and power consumption but may nevertheless still actively receive sensor readings. Alternatively, the user may initiate state **704** by pressing an input button on the wearable device for an extended period (e.g. more than 7 seconds) to simply turn the device off. Of course, these are merely examples and a person of ordinary skill in the art will appreciate that other configurations are possible, including enabling airplane made from the wearable device itself or the application, as well as turning the device off completely from the application or from the wearable device. In an exemplary embodiment, the wearable device has a button that enables airplane mode and allows the device to be turned off.

[0158] One key feature of an application in accordance with the present invention is detecting patterns in user data so that insights can be drawn and presented to users including the user-wearer or authorized users. Some of these insights may be used in detecting drug efficacy and user adherence to prescription. Insights may also be combined with other databases to suggest a diagnosis for the symptoms detected. Moreover, such insights may be utilized for generating alerts that automatically notify users of relevant information. The next figure references one exemplary method for providing insights.

[0159] FIG. **7**(*b*) is a flow chart depicting an exemplary method of deriving and presenting insights to a user in exemplary practice of an embodiment of the present invention. More specifically, FIG. **7**(*b*) shows method **700***b*; it is noted that although method **700***b* is shown in a particular sequence of steps, other conceivable sequence of the steps may be practiced without deviating from the scope of the present invention. In exemplary embodiments, an application is configured to generate and present specific insights to a user, for example a user of client device **103** or client device **104**.

[0160] As illustrated by method **700***b*, typically, a device such as client device **103** or client device **104** may receive data from the wearable device such as device **101** at step

710. As mentioned above, this may comprise communicating with the device directly or receiving data that was previously stored at a remote location such as at server **106**.

[0161] In step **720**, an application may detect patterns in user data and as a first check, the data from the wearable device may be normalized based on long-term averages and ranges.

[0162] In step **730**, the normalized data may be subject to pattern analysis using algorithms such as singular value decomposition or Fourier transform or cross-correlation.

[0163] In step **740**, the analysis of the resulting transformation may be utilized to produce insights.

[0164] Importantly, although these steps may be performed by, for example, an application situated at a client device, such as application **103***a* of client device **103**, in some embodiments, insights may be generated remotely, for example by software situated at server **106**.

[0165] In either scenario, at step **750**, insights generated by one or more programmable instructions situated on a client device or server may be presented to the user. An example use of the core body temperature is to detect if the wearer of the wearable device is suffering from parasitic fever. An example use of body temperature and voltage difference is to measure concurrently the body temperature and heart rate, which can be used to measure calorific output or identify stress and its cause.

[0166] Optionally, at step **760**, the analysis may also track variations in the patterns of user data. An example application is in the detection of heart rate variability, which can be used for identifying Hypoxic-Ischemic Encephalopathy in children.

[0167] Optionally, at step **770**, when there exists a baseline, variations from the baseline may be delivered to the user as alerts.

[0168] In an exemplary embodiment, insights detected by an application in accordance with the present invention may be presented to a user in the form of a graph with time as the x-axis variable. FIG. **7**(*c*) is a chart showing temperature as a function of time, which demonstrates such example. For example, and without limiting the scope of the present invention, measured body temperature may be displayed in a first color for normal and excursions outside the normal range may be displayed in a second color. Insights may also be derived using user input concerning certain events.

[0169] In exemplary embodiments, a graphical display of measurements (such as those displayed by the curve of graph **700***c*) may be supplemented by an overlay of notifications that arise from user actions such as the application of a certain medication. The end-result is a single view that shows measurements and user actions. An application of this method is in determining the effect of a medication on user's health as monitored by the wearable device. For example, a user may indicate via an input on their smartphone that they took a certain fever reducing medication shortly after time t_2 (in graph **700***c*). With this information, the application may track the effects of the medication during a period set **711** to provide feedback on things like, the effectiveness of the medication, whether a lower or higher dosage is required, etc. Optionally, the application may transmit the data stored locally to a server that hosts the data. Optionally, the application enables a user to enter reminders that notify the user when the timing is appropriate for a specific action, such as taking a new dose of medication.

[0170] Accordingly, an application in accordance with the present invention may be configured to display real-time information on a smartphone or tablet. Data may be stored internally (or locally) on a client device, and produce useful outputs such as graph **700***c*. In exemplary embodiments, the application providing insights may be kept up to date by using synchronization methods, or seeking information it has not previously received from the wearable device at regular or predetermined intervals. Several uses for and types of insights are disclosed below by way of illustration and are in no way intended to limit the scope of the present invention.

[0171] Estimation of Medicinal Cause and Effect: In some exemplary embodiments, an application in accordance with the present invention may be configured to determine whether the medication prescribed by the physician is taking effect. In such method, a user may be asked to enter into the application certain information such as the medication that is prescribed and the timings of reminders that the user desires (or presumably have been prescribed). The application may thus remind a user at the appropriate time and monitor the user's measurements to detect any response. One example may include the response to the administration of an antibiotic for a patient with a bacterial fever, which may be tracked by means of a reduction in the body fever. If no change is observed, then an alert is created for the medical provider.

[0172] Medicine Adherence: In some exemplary embodiments, an application in accordance with the present invention may be configured to use the patterns detected in the body temperature along with the knowledge of local epidemics to recommend a diagnosis to the patient's medical provider.

[0173] Ovulation Monitoring for Conception and Contraception: In exemplary embodiments, a specific insight that may be presented to the user is a fertility score. The application may implement known technics but utilize the basal body temperature derived using the method described above with reference to FIG. **6** in order to estimate the fertile days for a woman.

[0174] Fever Compensation for Ovulation Monitoring: In some exemplary embodiments, an application in accordance with the present invention may be configured for fertility tracking; in such embodiments, the application may compensate for fever for a more accurate prediction of a woman's fertility. Fever is detected as an elevation in the temperature measurements made by the wearable device. This elevation is measured and is compensated from the temperature measurements before it is used in the calculation of basal body temperature. The resulting basal body temperature is then used in the estimation of fertility score.

[0175] As such, these and many other methods maybe implemented utilizing information gathered by a wearable device in accordance with the present invention. Although, as mentioned above, it is possible for a wearable device to be configured for performing many of the above-discussed calculations, typically these calculations are left to more processor intensive devices such as client device **103**, in order to keep the wearable device as battery efficient as possible.

[0176] Moreover, as will be discussed in turn with reference to FIG. **8**, a wearable device in accordance with the present invention may implement algorithms to improve battery life. For example, in exemplary embodiments, communications from the wearable device to a client device may be throttled to by using a combination of several factors including rate of change in data, residual battery capacity and prior data transfers.

[0177] Communication is a key driver for power consumption. In order to minimize power consumption, methods exist to reduce the amount of communication based on the amount of data to be transmitted. Some methods use known techniques to reduce power consumed during transmission by using multiple different advertising packets or in different operating modes. However, that method does not take into consideration the amount of battery capacity left in the wearable device. In the present invention, the time interval between transmissions and the format for the payload may be derived from the amount of data to be transmitted, operating mode, and the residual battery capacity. FIG. **8** is a flow chart depicting an exemplary method of throttling data in exemplary practice of an embodiment of the present invention. More specifically, FIG. **8** shows method **800**; it is noted that although method **800** is shown in a particular sequence of steps, other conceivable sequence of the steps may be practiced without deviating from the scope of the present invention.

[0178] In step **801**, sensor data may be initially used to compute the rate of change of data.

[0179] In step **802**, the most recent sensor data, in combination with near-term history, may be used to determine the state of the device (as discussed above). Optionally, the state of the device may be set by other means, such as by the press of the button on the device or by a directive from the central device such as a phone.

[0180] In step **803**, a residual battery capacity estimator may implement measurements of battery voltage, duration of active use and amount of data communicated to estimate the amount of battery capacity left over.

[0181] In step **804**, the rate of change of data determined in step **801**, the device state determined in step **802**, and residual battery capacity determined in step **803** may be used by means of a linear equation to determine the payload format and the duration of the time interval to the next transmission.

[0182] It is well-known that the estimation of battery capacity using the voltage of the battery is not accurate because of the current drawn from the battery previously and variations from one sample of the battery to another. Accordingly, in exemplary embodiments, estimating the residual capacity of the battery using the time the wearable device has been in active operation, and the amount of data transmitted by it, may be implemented. Active operation may only include the time that the processor has been powered up.

[0183] In such exemplary method, the wearable device tracks the time of active operation and the number of data blocks transmitted. Using these values as independent variables, the wearable device uses a linear equation to estimate residual battery capacity. The coefficients for the linear equation are provided by the application in the client device during the provisioning process. The wearable device may execute this method either periodically or when a block of data is transmitted or both.

[0184] Of course, a person of ordinary skill in the art will appreciate that other methods may be implemented to maximize battery efficiency. For example, one method of increasing battery life may simply include detection of when the device is not being used in order to automatically shut it down, for example as mentioned above by detecting the state of the device.

[0185] Turning now to the next figure, FIG. **9** is a flow chart depicting an exemplary processing flow of typical programmable instructions on a wearable device in accordance with the present invention. More specifically, FIG. **9** shows method **900**; it is noted that although method **900** is shown in a particular sequence of steps, other conceivable sequence of the steps may be practiced without deviating from the scope of the present invention.

[0186] In steps **901-902**, measurements of the temperature and optionally, the voltage difference and/or the accelerometer may be received to generate the body's core temperature, the heart rate, heart rate variability, the respiration rate and sudden motion vector that comprise the data payload.

[0187] In step **903**, a determination may be made as to whether enough data has been collected. If sufficient data has been collected (e.g. an hour's worth of data), then this information may be computed and or stored in the wearable device's memory, for example in a local non-volatile RAM.

[0188] In step **904**, device state information may be derived from the computed data. For a device only containing the temperature sensor, the state could be converging, steady-state on body or steady-state off-body. Payload is derived from the data computed. Alerting bits in the payload are set based on the values of the data computed. For a device only containing the temperature sensor, the alerting bits that the core body temperature computed has exceeded normal range of human body temperature. Residual battery capacity is estimated and is used to schedule the next transmit time.

[0189] To transmit data, the wearable device starts broadcasting at step **905**. If it is unable to verify that the requesting client device is a trusted device, then via steps **906-908**, the connection may be rejected. If the requesting client device is a trusted device and the wearable device is able to authenticate the client device, then at step **909**, the device may receive a request for establishing a communication.

[0190] In steps **910**, the client device may want to respond based on the data received. In some embodiments, if this data is from a trusted device, the wearable device connects securely to this trusted device and either receives current date and time, sends history or updates whitelist.

[0191] When the connection is terminated, the wearable device completes advertising. If requested to shut down, at step **911**, the wearable device may shut down. Otherwise, a goes lower power mode may be initiated waiting for an interrupt to occur.

[0192] Accordingly, an important aspect of the present invention is in the security protocols used for onboarding the device, that is, in putting the device into use and periodically in communication with one or more client devices. To these ends, the present invention may implement methods such as geo-proximity and passkey security to ensure minimization of intrusion while a secure connection is established for sharing of encryption keys for subsequent communication. Using these methods, user data may be encrypted at the application level to offer security from eavesdroppers as well as malicious users that may gain access to a client device trusted by the wearable device. The next figure references one exemplary approach for enabling secured communications with a client device.

[0193] FIG. **10** is a flow chart depicting an exemplary method of communicating user data between a wearable device and a client device in exemplary practice of an embodiment of the present invention. More specifically, FIG. **10** shows transmission of user data from wearable device **101** to client device **103** running application **103***a*. Irrespective of the channel used for transmission, the wearable device encrypts user data at step **1002** based on the encryption keys that wearable device **101** received during onboarding at a previous step **1001**. Application **103***a* typically decrypts encrypted data if it knows the encryption key, which happens only if client device **103** running application **103***a* is authorized to receive that information. The scheme for encryption may be used even when user data is sent over a secured connection so that means are provided to application **103***a* to secure user data from a malicious user who gets access to client device **103** but is unable to gain access to application **103***a*.

[0194] In an exemplary embodiment, user data in a wearable device may be stored in an encrypted form. If the wearable device is for some reason compromised, this condition may be detected by the device's self-test. In this mode, the user data may be rendered unusable by for example, erasing the encryption key upon failure of the self-test, as described above.

[0195] Turning now to FIG. **11**, a flow chart is illustrated depicting an exemplary method of authorizing one or more devices to read data captured by a wearable device in exemplary practice of the present invention. More specifically, FIG. **11** shows method **1100**; it is noted that although method **1100** is shown in a particular sequence of steps, other conceivable sequence of the steps may be practiced without deviating from the scope of the present invention.

[0196] In this exemplary method, a wearable device may store identifying information concerning previously trusted client devices that have connected to the wearable device securely. This identifying information may be used to limit acceptance of connections from devices it has connected to. With reference to FIG. **11**, previously connected devices may be referred to as "trusted devices." As such, in exemplary embodiments, a wearable device may store a list containing identification numbers or otherwise identifiers for several trusted devices. A trusted device may then pass on the trust credentials to a secondary device so that it too can connect to the wearable device and get added to the list of trusted devices. When the wearable device is provisioned for use by the user, a client device not involved in the provisioning process (i.e. is not automatically added to a trusted device list) may use the following process to obtain authorization to access the wearable device.

[0197] In step **1101**, a new client device may request to connect to a wearable device such as wearable device **101**. In step **1102**, wearable device **101** may accept a limited unsecured connection to the new client device. Because the connection is unsecured, at step **1103** the new client device may read unsecured parameters provided by wearable device **101**. Typically, not being a trusted device, wearable device **101** will close the unsecured connection with the new client device since the new client device is not recognized for communication of user data.

[0198] In these instances, the new client device must obtain permission from the user of wearable device **101** to communicate with the wearable device. One way to achieve this is to request authorization from a previously provisioned device such as a trusted client device, wherein authorization comprises providing security keys from the trusted device to the new client device. In exemplary embodiments, a matrix code or other similar means may be implemented to obtain secured keys that were issued to the trusted client device.

[0199] Accordingly, in step **1105**, the new client device may request security keys. In step **1106**, the trusted client device may further request some type of authentication such as a passcode that may be provided by a user of the trusted client device to the user of the new client device in step **1107**. In some exemplary embodiments, utilizing a typical matrix code may obviate these last steps. The transfer of keys between devices may also be achieved over a secure connection, such as over a BLE connection. Optionally, the keys may be transferred using a server computer in the cloud.

[0200] In steps **1108-1109**, whatever method may have been implemented, typically results in the trusted client device providing the secured keys to the requesting new client device.

[0201] Accordingly, now the new client device will be recognized by wearable device **101** when requesting a secured connection at step **1110**; and at step **1111**, in response to a request by wearable device **101** for secured keys, the new client device may provide secure keys obtained from the trusted client device in previous steps.

[0202] Upon receipt of secured keys, having matched to encryption keys stored in a memory of wearable device **101**, a secured connection may be established at step **1113**. In exemplary embodiments, secure or encryption keys may be changed periodically by the wearable device and communicated to trusted devices in communication range.

[0203] At step **1114**, the new client device may access user data transmitted by wearable device **101**.

[0204] As a convenience measure, in exemplary embodiments, the new device may be added to a list of trusted devices. In other exemplary embodiments, wearable device **101** may further categorize the new device in a method that adds further security in the manner that wearable device **101** and authorized client devices communicate. Such method is discussed in turn.

[0205] FIG. **12** is a flow chart depicting an exemplary method of authorizing one or more devices to read data captured by a wearable device in exemplary practice of an embodiment of the present invention. More specifically, FIG. **12** is a flow chart depicting method **1200**, in which client device **103** is provisioned to communicate with wearable device **101**, and provides authorization to a new client device **1220** to communicate and read data from wearable device **101**. With method **1200**, multiple trusted client devices may access user data when they come in range of wearable device **101**; this includes the ability for trusted devices such as smartphones to seek historical data from the wearable device when the wearable device comes in range.

[0206] In an exemplary embodiment, wearable device **101** may categorize client devices in order to ensure that proper user permissions have been established. Such categories may be labeled for illustrative purposes as Type A, Type B, Type C, and Type D devices. Without limiting the scope of the present invention: a Type A device may refer to a device that has been previously provisioned to communicate with wearable device **101**; a Type B device may refer to a device that has been previously provided with encryption keys; a Type C device may refer to a device that has been previously provided with encryption keys by some other application (not a Type A device) but has been granted access to wearable device **101**; and a Type D device may refer to a device that has not been provisioned to communicate with wearable device **101**. In exemplary embodiments, wearable device **101** typically scans for devices filtered by a specific manufacturer ID or other identification, and determines whether to allow that discovered device to read user data, depending on the category or type of device discovered.

[0207] Accordingly, assuming client device **103** has not previously been provisioned with wearable device **101**, in step **1201**, when client device **103** seeks to communicate with wearable device **101**, wearable device **101** will see the device as a Type D device since client device is not yet in its database of previously discovered devices. At this step, wearable device **101** may initiate a provisioning protocol. In exemplary embodiments, an application on client device **103** may query the user whether the user wants to put client device **103** into use. If the user wants to use this device, the user may be required to enter a passkey or passcode granting secure access to wearable device **101**. If the user is unable to provide this passkey, then the user does not get secure access to the device and is therefore, not able to provision the device. As discussed before, the application allows the user to enter the passkey using several means such as manual entry, a visual scan of a static phrase or a visual scan of a blinking LED.

[0208] In step **1202**, assuming wearable device **101** and client device **103** share the same user, for example, then presumably the user of client device **103** has the required passcode and is able to provision or program client device (for the first time) to communicate with wearable device **101**.

[0209] In step **1203**, because client device **103** has been provisioned, wearable device **101** categorizes client device **103** as a Type A device for future pairing. Moving forward, client device **103** is able to retrieve in real-time the user data captured by wearable device **101**, including measurements that may be converted to graphs, tables or any form that is meaningful to the user via a display of client device **103** available for processes the data for further actions.

[0210] In step **1204**, supposing that another device is within range of wearable device **101**, for example client device **1220**, then wearable device **101** will see client device **1220** as a Type D device. Assuming client device **1220** is not, and will not be, provisioned (for example, it is a device belonging to a different user than the user of client device **103** and wearable device **101**), then client device **1220** will not be allowed to read user data.

[0211] However, the user of client device **1220** may approach the user of client device **103** and if desired, the user of client device **103** may provide authorization (and hence encryption keys) to access data on wearable device **101**. As mentioned with reference to FIG. **11**, this may be achieved via numerous methods, and in an exemplary embodiment a matrix code may be used to share the encryption keys between client device **103** and client device **1220** at step **1205**. As mentioned above, this may be desirable for example when a family member or caregiver may need access to user data of wearable device **101**.

[0212] Accordingly, after receiving the encryption keys in step **1205**, in step **1206**, wearable device **101** will discover client device **1220** as see it as a Type B device since client device **1220** has been previously provided with encryption keys. In this step **1206**, wearable device **101** may obtain identifying information to seek whether this device has been provided encryption keys by a proper authorizing party such as a Type A device.

[0213] In step **1207**, since client device **1220** was provided encryption keys from a Type A device (client device **103**), then wearable device **101** categorizes client device **1220** as a Type C device and allows it to read its data. Again, this may be achieved by various means including for example reading a device ID identifying client device **103** as the source of the encryption keys. Moving forward, client device **1220** is able to retrieve in real-time the user data captured by wearable device **101**, including measurements that may be converted to graphs, tables or any form that is meaningful to the user via a display of client device **103** available for processes the data for further actions. Of course, if the encryption keys are changed—as they may be periodically, then client device **1220** may be required to obtain new encryption keys following a similar method.

[0214] In step **1208**, a new device—for illustrative purposes client device **104**—may now try to read user data from wearable device **101**. Again, wearable device **101** will see client device **104** as a Type D device. Assuming client device **104** is not, and will not be, provisioned (for example, it is a device belonging to a different user than the user of client device **103** and wearable device **101**), then client device **104** will not be allowed to read user data.

[0215] As a measure of security, if at step **1209**, the user of client device **104** approaches the user of client device **1220** for authorization (and hence encryption keys) to access data on wearable device **101**, these keys will not be valid. This is because even though client device **1220** may have shared encryption keys with client device **104**, in step **1210**, wearable device **101** will see that it is a Type B device, and when seeking an identification of the source of the encryption keys, will not see a Type A as the source.

[0216] From the perspective of wearable device **101**, since client device **104** is neither a Type A or a Type C, client device **104** will not be granted access to read user data from wearable device **101**. Accordingly, an application on client device **104** is unable to retrieve the measurements made by wearable device **101**; if the application desires access to this device, then it must seek secure keys from an application that has access to the device, as explained in the above—for example from client device **103**.

[0217] Turning now to the last set of figures, FIG. **13**-FIG. **29** illustrate an exemplary user interface such as a graphical user interface (GUI) that may be distributed to a plurality of client devices in accordance with exemplary embodiments of the present invention. More specifically, these figures depict an exemplary client device **1300** such as a common smartphone that displays a user interface or mobile device application with different output displays that facilitate monitoring the health data that may be continuously provided by wearable devices in accordance with the present invention. In some embodiments of the present invention, a wearable device may include a thermal sensor for providing temperature data of the wearer to one or more users with access to client device **1300**. In other exemplary embodiments, the same user or a different user may further utilize a wearable device configured to generate voltage differential data of a wearer of the device. As such, these users or user may review and thus monitor their health by visualizing their data and being provided with some meaningful insights as well as functions that help the wearer or user to monitor their health.

[0218] With reference to FIG. **13** and FIG. **14**, output displays **1301** and **1401** are very similar. In the former, a display may exemplarily include certain indicators that provide immediate information to a user such as indicator **1302**, which includes the wearer's temperature. Other indicators may include indicator **1303** that may display the type of device being detected and from which client device **1300** is receiving the health data. For example, in the instant case an icon representative of a wearable temperature sensing device may be displayed. Indicator **1304** may be a data object such as a button to access certain settings of the mobile application as will be discussed further below. Indicator **1305** may be a similar button that provides access to a user management functionality for adding users and or associating users with a particular wearable device. Indicator **1306** may include an alarm icon or the like and may provide access to a reminder settings functionality to add, set, activate or disable reminders for different items such as medications, temperature readings, etc. as will discussed further below. Of course, a person of ordinary skill in the art will appreciate that other functionalities may be provided without deviating from the scope of the present invention, such as security measures via security input to prevent settings from being changed via indicator **1307**, or a help feature for providing guidance to a user via help indicator **1308**. Specifically, with regards to FIG. **14**, display output **1401** illustrates that naturally more or less complex information may be provided to a user, such as, for example, a temperature reading along with a graphical representation **1402** of a particular trend.

[0219] Some of the functionalities that may be provided via such an application to users of wearable devices in accordance with the present invention, may include visual and or functional prompts that guide the user to associate their wearable device with a particular client device. These functionalities not only enable a first time user to easily associate their device to their smartphone, but also ensures that their health data is kept secured.

[0220] Now with reference to FIG. **15**-FIG. **20**, FIG. **15** depicts display output **1501**, which may include a blinking indicator **1501** guiding the user to select said indicator so that they may add a user of their wearable device to the client device. That is, typically upon first use, a wearable device (for example having a thermal sensor) configured to provide temperature data, may initially allow for some communication of the temperature data while the device is paired with the client device **1300**. As such, a current temperature may always be displayed for a few initial minutes. However, because this may be the first time the device is set up, a centered indicator may display an ID associated with the wearable device. As mentioned above, an application or GUI for users of wearable devices in accordance with the present invention, may include visual and or functional prompts that guide the users to certain actions, including providing a limited set of actionable data objects, blinking data objects, or other types of prompts. For example, and without deviating from the scope of the present invention, because indicator **1501** is blinking, or for example may be the only enabled indicator available to the user, the user will be guided to select indicator **1501** to add and or associate their wearable device to a particular user.

[0221] As such, in FIG. **16**, a display output **1601** may be provided by the application, wherein a user identification prompt **1602** and a user information request prompt **603** may be displayed, requesting the user to provide said requested information. This may be achieved in a typical fashion, without deviating from the scope of the present invention.

[0222] Upon saving a particular user, a display output **1701** as exemplarily shown in FIG. **17** may be provided, in which a list display **1702** of previously entered users may be generated for the user in order to enable the user to select the desired user they will be associating with the new wearable device. A typical confirmation or save button **1703** may be provided to save this user request.

[0223] As shown in FIG. **18**, once a user has been selected, a display output **1801** may prompt the user to verify, register and or authenticate the wearable device, and as such associated it to the selected user. Accordingly display output **1801** may include an authorization functionality such as a two-dimensional barcode matrix reader—for example a QR™ code reader, requesting or prompting the user to read such identification code on the wearable device or a packaging or literature of the wearable device. Accordingly, in exemplary embodiments, device **1300** may be utilized to read code **1803** upon request **1802** to read the same and display the associated ID **1803** of the wearable device that was initially displayed via indicator **1502**.

[0224] As shown in FIG. **19**, a following display output **1901** may then be provided including information display **1902**, wherein a user may confirm and thus associate the selected user with the registered wearable device via a typical confirmation button **1903**.

[0225] As a person of ordinary skill in the art will appreciate, a typical following screen **2001** may be provided as in FIG. **20**, in which a summary of the registered device and associated user information **2002** is displayed with a simple completion button **2003**. From a backend perspective, this process, although seamless to the user, may be as complex as the security protocols discussed above, or as simple as a pairing of the device to the client device **1300**, without deviating from the scope of the present invention. Typically, however, various levels of encryption are implemented to make sure that no other device received the health data—whether temperature data or voltage differentials, or otherwise, sent between wearable device and client device.

[0226] Now with reference to FIG. **21** and FIG. **22**, a user may be exemplarily guided to their settings functionalities. For example, a display output **2101** may include an indicator **2102** that is blinking, lit up, the only activated or enabled function or otherwise interactable object data to guide the user to select the same. Selecting indicator **2102** may provide the user with display output **2201** in FIG. **22**, in which various settings and options are provided to the user, including but not limited to: a temperature range indicator **2202** for setting off reminders or notifications; a temperature units selector **2203** for selecting the preferred temperature units to display; a contact number list **2204** for sending notifications or alerts to other client devices (such as a physicians client device, a parent's smartphone or otherwise, and or adding additional contact client devices; and or a selectable list **2205** of reminders, including for example reminders associated with a medication time, or a device condition reminder to alert the user of times for taking a medication or alerts associated with a low device battery. With regards to the latter, while the settings display may provide a user to select the types of alarms, notifications and reminders, another display output may be dedicated to control the same.

[0227] With reference to FIG. **23**-FIG. **25**, a display output **2300** may include an indicator **2302** to guide the user to control, add or delete a particular type of reminder, alarm, notification or otherwise. For example, and without limiting the scope of the present invention, upon selecting indicator **2302**, may provide the user with display output **2401** in FIG. **24**, in which a typical reminder functionality may be provided via a reminder prompt **2402**. As a person of ordinary skill in the art may appreciate, prompt **2402** may include adding a type of reminder (for example whether for medication, temperature reading or device condition), as well as a time and date and frequency of the reminder, alert or notification. FIG. **25**, for example, may be a display output **2501**, which includes an indicator **2502** that alerts the user to a particular reminder—such as taking a medication at a previously scheduled time. Of course, other types of notifications may be incorporated via the exemplary application, including typical notifications outside of the application, including text messages, emails, audio alarms and the like.

[0228] Now with reference to FIG. **26** and FIG. **27**, examples of display outputs associated with tracked temperature data are provided. For example, display output **2601** may include a simple and concise display of a temperature reading via an indicator **2602**, that in addition to a temperature measurement includes statistical data in a simplified graphical format **2603**. In some exemplary embodiments, because more information may be available to a user, such as statistical information associated with the temperature data displayed via indicator **2602**, indicator **2602** may be blinking or otherwise prompting the user as mentioned above. As such, upon interacting with indicator **2602**, a new display output **2701** on FIG. **27** may be provided, wherein a graphical representation such as the one discussed with reference to FIG. **7**(*c*) may be provided via client device **1300**. Moreover, other features such as navigational functionalities **2703** may be provided to allow the user to gain valuable insights into statistics such as how well a medication is working, or whether the medication is working at all.

[0229] As mentioned above, such a mobile application may include functionalities for a wearable device in accordance with a device such as that disclosed with reference to FIG. **5**(*a*)-(*e*). Accordingly, FIG. **28** and FIG. **29** display exemplary display outputs **2801** and **2901** that may be provided to display data that may be captured by said device. For example, and without deviating from the scope of the present invention, display output **2801** may include an alert indicator **2802** that indicates a normal voltage differential data from the user. In some exemplary embodiments, selecting indicator **2803** may provide a user with several settings, such as: an event history selection prompt **2902**; a data tracking prompt **2903** for providing data tracking options; a contact number list **2904** for sending notifications or alerts to other client devices (such as a physician's client device, a parent's smartphone or otherwise, and or adding additional contact client devices; and or a selectable list **2905** of reminders, including for example reminders associated with a medication time, or a device condition reminder to alert the user of times for taking a medication or alerts associated with a low device battery.

[0230] It is an objective of the present invention to address the problems raised above and to further improve the quality of the experience provided to the user. It is another objective of the present invention to minimize latency in accurately measuring body core temperature of a user, so that information may be gleaned and acted upon quickly as needed. It is another objective of the present invention to provide reliable communication between the wearable device and client devices. It is yet another objective of the present invention to increase efficiency and generally prolong battery life. It is another objective of the present invention to allow multiple trusted client devices to access user data when they come in range of the wearable device. It is yet another objective of the present invention to protect user data from unauthorized access by storing and transmitting data securely. It is yet another objective of the present invention to generate insights from data collected. It is yet another objective of the present invention to provide alerts and notifications to various entities depending on the nature of the alert and status reports desired by the entity. These advantages and features of the present invention are not meant as limiting objectives, but are described herein with specificity so as to make the present invention understandable to one of ordinary skill in the art

[0231] A system and method of continuous health monitoring has been described. The foregoing description of the various exemplary embodiments of the invention has been presented for the purposes of illustration and disclosure. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching without departing from the spirit of the invention.

What is claimed is:

1. A wearable device, comprising:

a flexible printed circuit board (PCB) that is folded to form multiple layers;

a temperature sensor situated on a first surface of a first layer of the PCB;

a circuit including a thermal contact region etched on a second surface of the first layer of the PCB, the circuit further including one or more heat pathways connecting the thermal contact region of the circuit to the temperature sensor;

a communication transmitter including an antenna situated on one of the multiple layers of the PCB; and

a microprocessor in communication with the temperature sensor and the communication transmitter, the microprocessor configured to continuously obtain temperature sensing data from the temperature sensor and transmit the sensing data to one or more client devices.

2. The wearable device of claim **1**, further comprising

a fold in the PCB adapted to receive a battery for powering the PCB, the fold connecting the circuit of the PCB to a cathode and to an anode of the battery.

3. The wearable device of claim **1**, wherein the one or more heat pathways comprise of a vertical interconnect structure (VIA) between the first layer and the second layer of the PCB, the VIA configured to conduct heat from the thermal contact region to the temperature sensor.

4. The wearable device of claim **3**, wherein the microprocessor is further configured to use a residual battery capacity to determine a transmitter payload.

5. The wearable device of claim **3**, wherein the microprocessor is further configured to throttle a payload of sensing data, by:

computing a rate of change of the temperature data;

determining a state of the wearable device;

estimating a residual battery capacity; and

determining a payload format including a duration of a time interval to a next transmission in order to throttle the transmitted sensing data to the one or more client devices.

6. The wearable device of claim **3**, wherein the microprocessor or at least one of the one or more client devices is further configured to compute a basal temperature of the wearer by:

receiving time-stamped sensing data including body temperature and a state of the wearable device;

implementing a buffer range of temperature data; and

determining the basal body temperature by ignoring body temperature data within the buffer range.

7. The wearable device of claim **3**, further comprising a housing adapted to secure the PCB, the housing including:

a first plastic layer adapted to receive the PCB; and

a second plastic layer including an aperture for exposing the thermal region of the PCB.

8. The wearable device of claim **7**, wherein the second plastic layer further comprises a thin layer over the aperture between the thermal contact region and the exterior of the housing.

9. The wearable device of claim **7**, wherein the second plastic layer comprises a middle layer adapted to threadedly secure the PCB therein, and further comprising a third plastic layer for sandwiching the PCB threadedly secured in the middle layer between the first and third plastic layers.

10. The wearable device of claim **3**, further comprising a heat guide, including:

a thermal insulation applied on top of the temperature sensor and the thermal contact region, the heat guide for drawing heat energy from a body of a user to the temperature sensor and minimizing a heat loss.

11. A system for continuous health monitoring, comprising:

a server for storing health data including temperature data;

one or more client devices configured to display information associated with the temperature sensing data; and

a wearable device including:

a flexible printed circuit board (PCB) that is folded to form multiple layers;

a temperature sensor situated on a first surface of a first layer of the PCB;

a circuit including a thermal contact region etched on a second surface of the first layer of the PCB, the circuit further including one or more heat pathways connecting the thermal contact region of the circuit to the temperature sensor;

a communication transmitter including an antenna situated on a one of the multiple layers of the PCB; and

a microprocessor in communication with the temperature sensor and the communication transmitter, the microprocessor configured to continuously obtain temperature sensing data from the temperature sensor and transmit the sensing data to the one or more client devices.

12. The system of claim **11**, further comprising

a fold in the PCB adapted to receive a battery for powering the PCB, the fold connecting the circuit of the PCB to a cathode and to an anode of the battery.

13. The system of claim **11**, wherein the one or more heat pathways comprise of a vertical interconnect structure (VIA) between the first layer and the second layer of the PCB, the VIA configured to conduct heat from the thermal contact region to the temperature sensor.

14. The system of claim **11**, wherein the microprocessor is further configured to use a residual battery capacity to determine a transmitter payload.

15. The system of claim **11**, wherein the microprocessor or at least one of the one or more client devices is further configured to throttle a payload of sensing data, by:

computing a rate of change of the temperature data;

determining a state of the wearable device;

estimating a residual battery capacity; and

determining a payload format including a duration of a time interval to a next transmission in order to throttle the transmitted sensing data to the one or more client devices.

16. The system of claim **11**, wherein the microprocessor or at least one of the one or more client devices is further configured to compute a basal temperature of the wearer by:

receiving time-stamped sensing data including body temperature and a state of the wearable device;

implementing a buffer range of temperature data; and

determining the basal body temperature by ignoring body temperature data within the buffer range.

17. A method for continuous health monitoring, implemented by a wearable device and an executable graphical user interface (GUI) distributed to one or more client devices in communication with the wearable device, comprising:

receiving temperature data from one or more sensors on a flexible printed circuit board (PCB) of the wearable device that is folded to form multiple layers, wherein at least one of the one or more temperature sensors are situated on a first surface of a first layer of the PCB, the PCB including a circuit comprising a thermal contact region etched on a second surface of the first layer of the PCB and one or more pathways connecting the thermal contact region of the circuit to the temperature sensor;

generating one or more data packets associated with the temperature data; and

sending via a communication transmitter including an antenna situated on one of the multiple layers of the PCB, the one or more data packets associated with the temperature data to a client device.

18. The method of claim **17**, further comprising:

receiving, by the client device, the temperature data from the wearable device worn by a user, the temperature data including an instantaneous temperature of the user;

computing, by the client device, a basal body temperature of the user for a predetermined period; and

deriving, from the basal body temperature of the user, an estimated fertility period for the user.

19. The method of claim **18**, further comprising:

prior to computing the basal body temperature, detecting an elevation of the body temperature; and

compensating for the elevation of the body temperature.

20. The method of claim **18**, further comprising:

launching, by the GUI in response to receiving the temperature data, an initial screen displaying a current temperature reading of a wearer of the wearable device; and

prompting a user of the GUI to tag the temperature reading by providing a limited set of actionable data objects on the screen display or by guidance from a blinking data object.

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摘要(译)

本发明涉及一种实现可穿戴设备的系统和方法，该可穿戴设备采用柔性印刷电路板（PCB），其包括温度传感器。 PCB可以印刷在柔性基板上，该柔性基板可以折叠以形成配置成容纳传感器和天线的多个层。传感器可以容纳在所述层内并且位于可以印刷在PCB上的通路的终端，其中该通路用作接触以及从用户的身体到传感器的热导管。天线可以以这样的方式容纳在柔性PCB的层内，使得保持适当的信号传输并且使等待时间最小化。温度读数可以无线传送到一个或多个客户端设备，其实现适合于生成关于用户的健康方面的见解的一个或多个算法。